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THE PALAEOMAGNETISM OF THE CAINOZOIC BASALTS FROM AUSTRALIA

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[Communicated by Professor E. S. Hills, 11 July 1957]

Abstract

The magnetic properties of the Cainozoic Volcanics from their type area in Victoria are examined in detail to give the broad picture of the behaviour of the Earth's magnetic field as it existed at the time of extrusion of these Volcanics. On the basis of the direction of magnetization of stably magnetized samples, a clear-cut division is found to exist between the Older Volcanics of Gippsland and the Newer Volcanics of the Western District and, since such a division should be found by sufficient sampling to exist for all other Cainozoic Volcanics, the possibility of this new method for stratigraphical correlation is illustrated by a few palaeomagnetic measurements of Volcanics from elsewhere in eastern Australia.

Numerous specimens from both the Older and Newer Volcanics are found with the direction of magnetization reversed, which is important in geophysical prospecting and may be of value for detailed geological mapping.

The plausible dipole assumption for the steady-state condition of the Earth's magnetic field is used in conjunction with the palaeomagnetic measurements to advance the idea of limited polar wandering during the Cainozoic.

Introduction

In some rocks the directions of remanent magnetization may be identified with the direction of the geomagnetic field at the time and place of deposition, and, in recent years, some success has attended the efforts which have been made to explore the variations in the geomagnetic field in remote ages by measuring in the laboratory the directions of magnetization of rock specimens whose geological age and field orientation are known. Igneous rocks owe their magnetization to the presence of a large number of small particles of ferrimagnetic minerals, usually opaque oxides of the system FeO-Fe_2O_3-TiO_2. These are scattered in a matrix of paramagnetic or diamagnetic minerals such as quartz, amphibole or felspar, which make up the bulk of the rock but which do not contribute to the remanent magnetization. Most of these ferrimagnetic minerals have Curie temperatures between 200 and 700°C., above which they are paramagnetic, and, on cooling down through these temperatures in a magnetic field, they acquire a permanent magnetic moment in the field direction. This is thermoremanent magnetization, and the ferrimagnetic minerals in igneous rocks become magnetized in this way on cooling in the Earth's magnetic field.

The direction of the geomagnetic field is specified by the angles of declination (D) and inclination (I). D is the aximuth of the horizontal magnetic force and is reckoned in degrees east of geographic north. I is the angle between the total magnetic force and the horizontal plane and is reckoned negative if the south-seeking compass direction is below this plane and positive if above it. Nowadays the horizontal component of the geomagnetic field is aligned approximately north-south, so that D is usually small over most of the Earth's surface. The inclination varies between 0° and 90°. It is low near the equator and high in polar latitudes; negative

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in the southern hemisphere and positive in the northern hemisphere. At any one place the field direction undergoes periodic changes through 20° or 30° over hundreds or thousands of years. This is called the secular variation. Although this variation is very complex in detail, the average direction of the field over periods of time of several thousands of years or more at any place of observation is parallel to a line of force in the field of a theoretical dipole situated at the centre of the Earth and directed along the axis of rotation, that is—

$$D = O, \qquad (1)$$

and

$$\tan I = 2 \cot \theta \qquad (2)$$

where θ is the co-latitude of the place of observation. Some thousands of years is a very short period compared with the time taken for a thick rock formation to accumulate, so that the average magnetic direction of many specimens selected so as to span the thickness of such a formation is this dipole field direction, and the effect of secular variation is averaged out.

This communication gives an account of palaeomagnetic work on some of the Cainozoic volcanic rocks of Australia. It contains complete experimental data, and its main object is to discuss the possible uses of this work in aiding geological correlations. Other papers (Irving and Green, 1957a, b) deal more specifically with the geophysical aspects and attempt an integration with equivalent results from elsewhere in the world.

The Cainozoic lavas of Australia are for the most part olivine basalts, and cover an area of approximately 50,000 square miles, mainly in the eastern states. In Queensland. New South Wales, South Australia, Victoria and Tasmania their position within the Cainozoic, in general, cannot be fixed with any great accuracy, but in Victoria, where there is often contact with fossiliferous sediments, they are more adequately dated and may be divided into two main groups (Singleton, 1939) which differ in age, petrology (Edwards, 1937, 1938) and geomorphological relationships (Hills, 1938). For this reason, sampling has been concentrated in these two groups, which are known as the Newer and Older Volcanics of Victoria.

The Newer Volcanics have a more or less continuous outcrop to the west of the meridian of Melbourne. They overlie the marine Tertiaries of this region and cannot be older than Pliocene—in fact, it is certain that the bulk of the lavas belong to the Pleistocene—but it is possible that some of the earlier flows are Pliocene in age. The youngest flows are geologically Recent. The Newer Volcanics have been faulted in places, but tilting of the lava field has been negligible.

The Older Volcanics, sometimes called the Narracan Volcanics, outcrop mainly to the east of Melbourne and are interbedded with non-marine sediments which form part of the Tertiary sequence in Victoria. In the area sampled they are believed to represent a single stratigraphic entity which is certainly Lower Tertiary in age and probably Eocene. This Lower Tertiary sequence has been deformed by later Tertiary movements, but these have not been extensive and steeply dipping beds are restricted to the neighbourhood of faults and monoclinal folds. There is no metamorphism. The present discontinuous outcrops have resulted from erosion subsequent to this deformation.

Both groups have been extensively sampled and show two important features:

1. Within each group the average direction of magnetization regardless of sign remains approximately constant, but repeated reversals of polarity occur. Sometimes the magnetizations are normal (—ve) with the south

pole directed below the horizontal plane, and sometimes reversed (+ve) with the north pole downwards.

2. In the Newer Volcanics the average direction of magnetization has an inclination of 59·8°, whereas in the Older Volcanics the mean inclination is 13·1° steeper.

These two features are referred to, respectively, as reversals and change of the average direction. Reversals occur several times within each group, whereas the change from the steep inclination in the Older Volcanics to the lower value in the Newer Volcanics is a much slower process. Reversals may be interpreted (there are alternative explanations) as indicating reversals in the sign of the geomagnetic field, but the change in direction of magnetization between different rock formations is thought to be due to an entirely different geophysical process, namely, a change in the attitude of the mean magnetic axis of the Earth relative to the outer layers (Creer et al., 1954). The directions in the Newer Volcanics are such as could have been acquired in the field of a geocentric dipole whose axis, which will be called the mean geomagnetic axis, coincides with the present axis of spin. On the other hand, the mean geomagnetic axis consistent with the magnetization of the Older Volcanics is at an angle of 23·2° to this.

In the other states of the Commonwealth, attempts by purely geological methods to extend the two-fold division established in Victoria have been successful to some extent, but in many cases it is impossible to define ages with any degree of certainty. The difference in direction between the Older and Newer Volcanics in Victoria should exist in basalts of earlier and later Cainozoic age elsewhere, so that palaeomagnetic data may be of assistance in stratigraphic correlation. The possibilities of this method are illustrated by comparing some magnetic results from basalts in Queensland, New South Wales and Tasmania with the "standard" results from Victoria.

Experimental Methods

Fresh hand specimens were taken mostly from quarries, road cuttings and sea cliffs. Thirty microscope slides were examined to test for incipient weathering which may not be detectable in hand specimens. In all cases the outlines of the iron minerals were clean and there was no indication of weathering which could have altered the initial magnetic properties.

The hand specimens were orientated prior to extraction from the rock face by standard geological techniques. Cylinders were machined from these with non-magnetic tools, orientation being preserved during the process. The directions of magnetization and susceptibility of these cylinders were measured on the magnetometer described previously (Irving, 1956a).

The method used here of conducting a palaeomagnetic survey of volcanic formations with optimum sample economy has been described previously (Watson and Irving, 1957). For the general survey of the Victorian lavas, samples have been taken from as many sites as possible spread over the outcrop, with two or three samples at each to minimise experimental error. In this way inhomogeneities due to the secular change of the geomagnetic field and geological tilting are averaged out, and a wider regional picture is obtained than would otherwise be the case if the same number of samples were distributed among fewer sites. Errors due to geological tilting have been reduced to a minimum by using only those sites at which the beds are known to be flat-lying or dipping by less than 5°. The effect

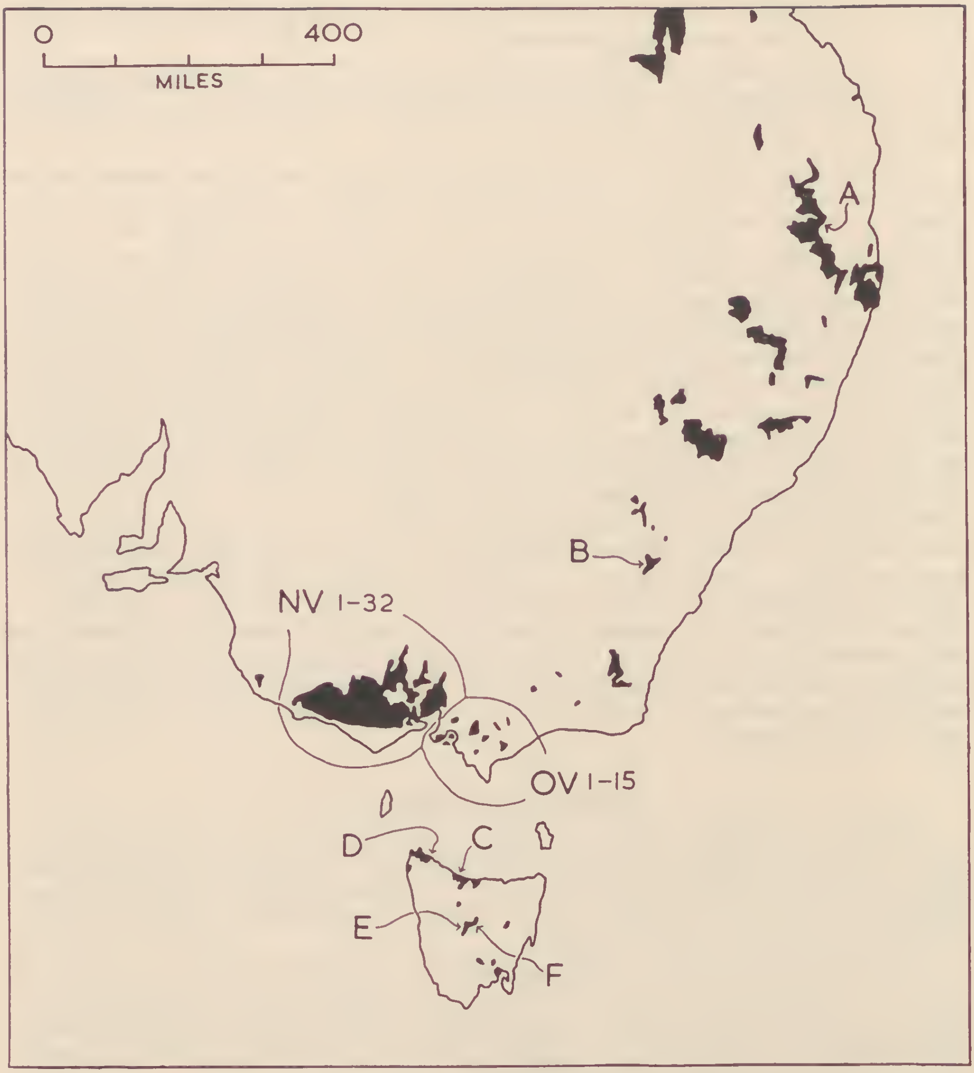

Fig. 1.—Sketch map of south-eastern Australia showing the outcrop of the Cainozoic volcanics and the areas sampled.

of this will be lost in any case when results from many localities are averaged, and the present horizontal will be a close approximation to the horizontal at the time of deposition.

The areas from which collections were made are shown in Fig. 1. Locality and sampling details are listed in Table 3. The distribution of sites in Victoria is shown in Fig. 2, and the region in the neighbourhood of Melbourne in greater detail in Fig. 3. In the Newer Volcanics, 2 samples were taken at each of 30 sites and the

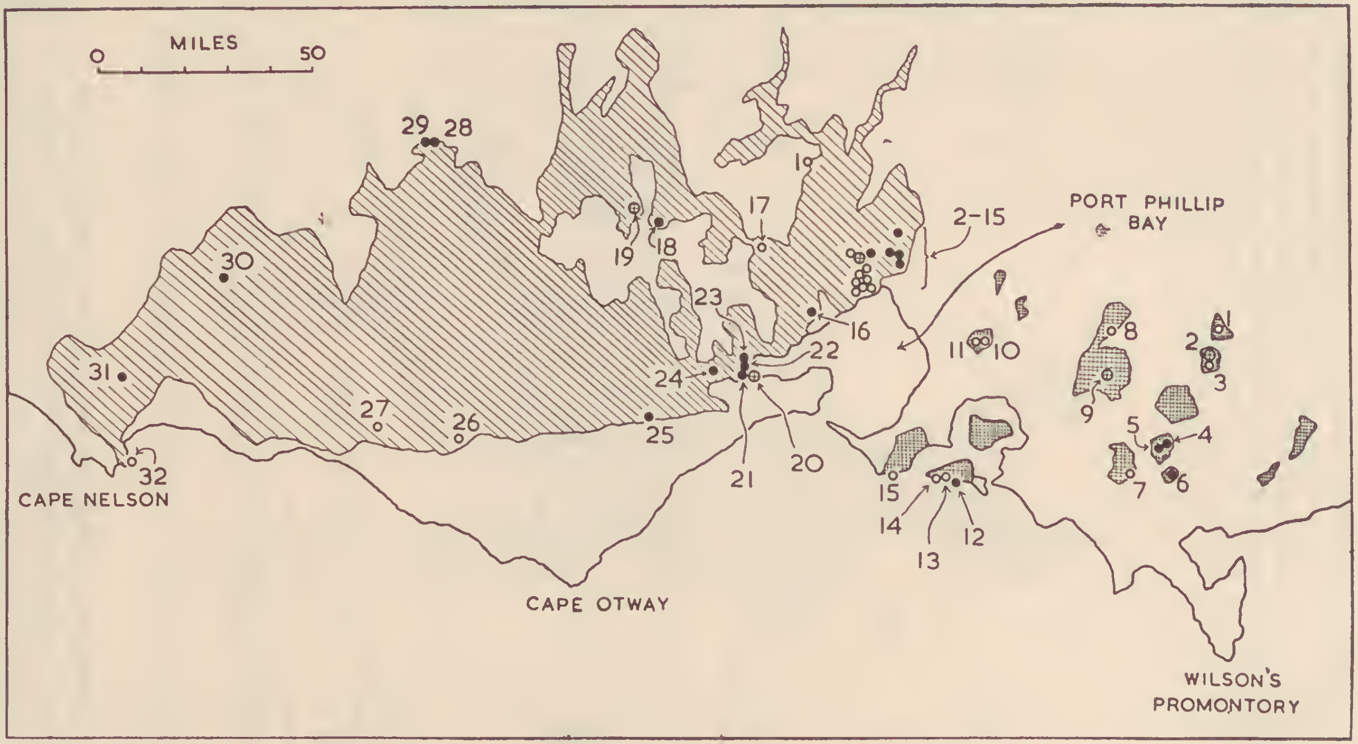

FIG. 2.—Distribution of sampling sites in Victoria. The outcrop of the Older Volcanics is indicated by cross-hatching and that of the Newer Volcanics by oblique shading. The sites are numbered as in Table 3. Sites with normal, reversed, and mixed polarities are indicated by circles, dots, and circles with crosses, respectively.

area covered is approximately 10,000 square miles; 2 sites (NV10, NV15) were sampled in detail to test for consistency within a single lava flow. In the Older Volcanics only 15 suitable sites were found and, because of this, 3 samples were usually obtained at each. The coverage is about 5,000 square miles. Outside Victoria

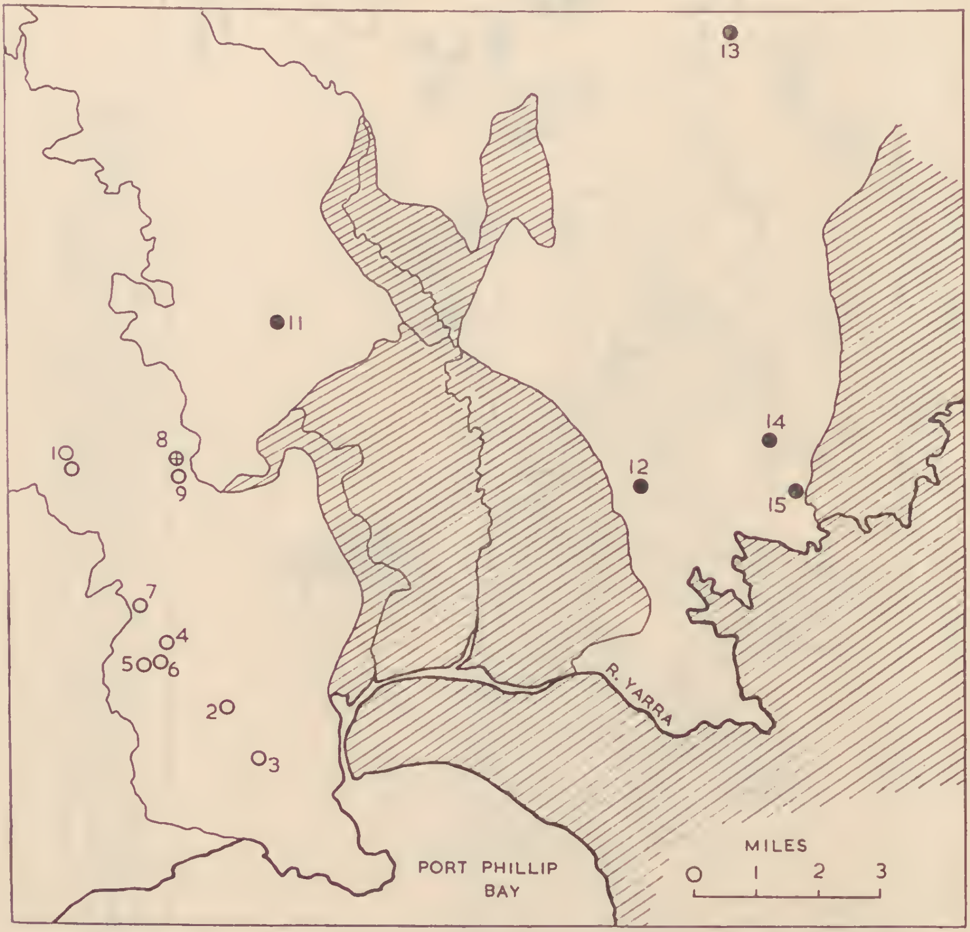

Fig. 3.—Distribution of sampling sites in the Newer Volcanics of the Melbourne area. The basalt outcrop is left blank, and the sites are numbered and marked as in Fig. 2.

the collecting sites are scattered over eastern Australia, 2 or more samples being obtained at each.

The Directions of Magnetization of the Victorian Lavas

The directions of magnetization are shown on equal-area projections in Figs. 4 to 7. The plane of the projection is always the horizontal plane and plotting is always on the upper hemisphere. The degree of uniformity at 2 quarries is illustrated in

Fig. 4. There is good agreement at the individual sites and irrespective of sign there is reasonable agreement between sites.

The mean directions at 32 sites in the Newer Volcanics are plotted in Fig. 5; 13 sites have the polarity of the present field (north-seeking polarization upwards) and 16 are of opposite polarity, the two groups being exactly 180° apart; 3 sites have mixed polarity. The overall mean direction, regardless of sign, is parallel to the geocentric axial dipole field (Table 1, Fig. 7). The mean site directions in

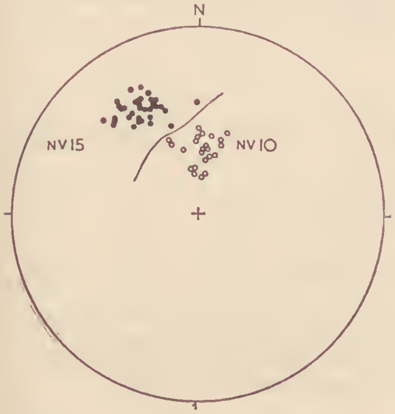

Fig. 4

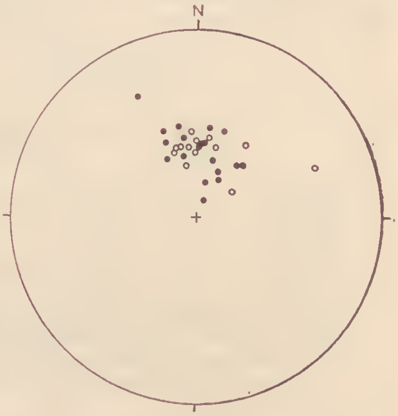

Fig. 5

Fig. 4.—The directions of magnetization at Albion Quarry, Sunshine (NV10) and at Adam's Quarry, Alphington (NV15). North-seeking directions are indicated by circles (normal) and south-seeking directions by dots (reversed).

Fig. 5.—The mean directions of magnetization at 32 sites in the Newer Volcanics of Victoria. Sites with normal directions indicated by circles, and those with reversed directions by dots. Sites with mixed polarities are indicated by crossed circles.

Fig. 6

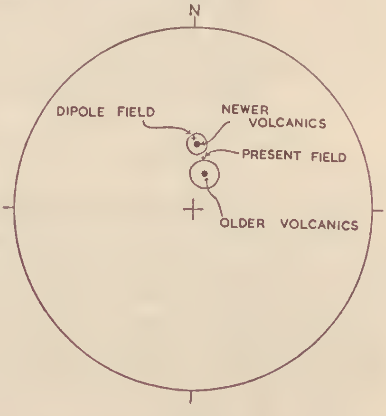

Fig. 7

Fig. 6.—The mean directions of magnetization at 15 sites in the Older Volcanics of Victoria. Legend as for Fig. 5.

Fig. 7.—The average directions of the Newer and Older Volcanics of Victoria. The average directions of magnetization are indicated by dots with error circles at $P = 0{\cdot}05$. Present field direction shown by crosses.

the Older Volcanics are given in Fig. 6; 9 sites have negative inclination, 4 are positive, and 2 sites have mixed polarity. The data are insufficient to test the exactness of these reversals. The average direction of the whole group, regardless of sign, is given in Table 1 and Fig. 7. The inclination is steeper than in the Newer Volcanics and the declination is easterly.

TABLE 1

The Directions of Magnetization in the Victorian Volcanics and the Pole Positions consistent with these Directions

	Average direction of magnetization			Sampling area		Pole position			
	D	I	α P=0·05	Lat.	Long.	Lat.	Long.	δ m P=0·05	δ p P=0·05
Newer Volcanics	3·4	−59·8	4·8	38·0S	143·5E	86·3S	102·1E	7·2	5·5
Older Volcanics	15	−72·9	6·8	38·0S	145·5E	66·8S	122·7E	12·1	10·8

D and I are the declination and inclination of the average directions. α is the Fisher error (Fisher, 1953) calculated from a modified formula (Watson and Irving, 1957). The pole positions are specified by latitude and longitude; δ p and δ m are the pole errors in the direction of and at right angles to the colatitude (Irving, 1956a).

The occurrence at 5 sites (Fig. 2) of mixed polarities is a matter of some interest. Contiguous samples with opposed polarities have been noticed previously in these basalts by Rayner (private communication). Three possible explanations may be given:

1. At each of these sites several lava flows, although not distinguishable, may in fact be represented, so that the specimens can have cooled through the Curie temperature at different times between which the magnetic field reversed.
2. Self-reversal processes of the type mentioned later under "Reversals of Magnetism" may have operated.
3. Errors in orientation may have occurred despite the great care taken to avoid them.

The Position of the Pole in the Past relative to Australia

It has been pointed out in the introduction that the average direction of magnetization of a rock formation is parallel to a line of force in the Earth's dipole field. From this average direction the axis of this dipole field may be calculated and also the positions of the points or poles at which this axis intersects the Earth's surface (Irving, 1956b). The pole positions consistent with the directions of magnetization of the Older and Newer Volcanics are given in Table 1 and plotted in Fig. 8.

The pole for the Newer Volcanics coincides with the present geographic pole, showing that the Earth's magnetic field during the past million years has been, so far as this part of the world is concerned, on average that of a geocentric axial dipole. The Older Basalt pole is on the fringe of the Antarctica and much nearer Australia. Previous work on the dolerite sills of Tasmania (Irving, 1956a) and the lavas and glacial varves of the Kuttung Series of New South Wales (Irving,

1957a, b) has defined the pole positions for the Jurassic and Upper Carboniferous. They lie in what is nowadays the region of the Tasman Sea and, with the Older Volcanic pole, fall consecutively on a path leading in a broad sweep to the pole for the Newer Volcanics and the present geographic pole. Since the magnetic and rotational poles have coincided during the past million years, it may be suspected that they always have been coupled together, so that the path in Fig. 8 is also the path of the geographic pole relative to Australia. Evidence in support of this view is found in the deposits of glacial origin which occur in the Upper Carboniferous in many parts of Australia. These deposits indicate frigid conditions such as are most

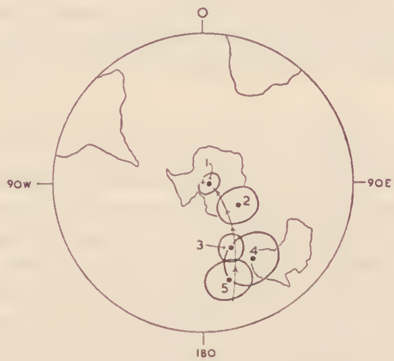

FIG. 8.—The position of the pole relative to Australia in the past. The pole positions are numbered as follows: 1 Newer Volcanics of Victoria, 2 Older Volcanics of Victoria, 3 Tasmanian dolerite sills, 4 Kuttung Volcanics, 5 Kuttung sediments.

likely to have arisen in a high geographic latitude, just as the palaeomagnetic results indicate a high geomagnetic latitude. Theoretical reasons connected with the origin of the geomagnetic field also suggest that the two poles will always have coincided (Runcorn, 1954). The evidence in Fig. 8 would suggest therefore that in Carboniferous times the south geographic pole was just to the east of Australia and has since moved gradually away, reaching its present position during Upper Tertiary times.

Reversals of Magnetization

Reversed magnetizations were noticed first in the Cainozoic basalts of Australia by Mercanton (1926) in 3 specimens from Queensland, and again by Rodgers (1952) in 4 specimens from the Armidale region, and by Almond, Clegg and Jaeger (1956) in one bore-core specimen from Tasmania. Rayner (1937, 1940) has inferred from local anomalies in the geomagnetic field in central New South Wales and New England that the directions in underlying basalts are in some cases reversed. In addition to these and the reversals in Victoria, the authors have found reversely magnetized basalt at Toowoomba in Queensland and at Berrima in New South Wales (see Table 3).

Reversals of magnetization could result either from complex processes affecting the iron minerals (Neel, 1951) or from reversals in sign of the Earth's magnetic field without change in direction of the dipole axis. Both may have occurred. The first and, so far, the only laboratory demonstration of self-reversal properties in a naturally occurring rock has been given by Nagata et al. (1952) for a dacite

from Mt. Haruna in Japan. This rock possesses a reversed natural remanent magnetization and, when cooled from above the Curie temperature in the Earth's field, takes on a magnetization parallel to this field but opposite in sense. Six specimens of reversed basalt from Victoria, when treated in the same manner, acquired a magnetization with the same sense as this field, as is the case in all re-heating experiments so far conducted on basalts from elsewhere in the world. This would seem to suggest that these basalt reversals reflect a change in sign of the geomagnetic field, but it must be recognized that during re-heating experiments the delicate self-reversing property may be destroyed and such tests are not therefore decisive.

Reversed magnetizations are a characteristic feature of the Cainozoic volcanics of Australia just as they are in equivalent lavas in the Northern Hemisphere, but until more field and laboratory data are available from them it is impossible to say whether or not they indicate reversals in sign of the geomagnetic field in Australia during the Cainozoic.

Application of Palaeomagnetism to Problems in Geological Correlation

Reversals may, in future, be of some assistance for the relative dating of beds within a rock formation. For instance, if the whole of the lower part of a rock formation is reversed whereas the upper is normal, the magnetic polarity becomes a characteristic of considerable value for correlation purposes. As often happens, however, beds with reversed and normal magnetizations alternate in serial fashion, so that the occurrence of a reversed magnetization in a specimen of unknown age does not allow it to be allocated to any specific level. A survey of all the known outcrops of the Newer Volcanics, paying attention to the polarity only, could be achieved very quickly and may be of help in mapping these lavas whose detailed chronology is at present so uncertain.

The changes in average direction of magnetization are more important for correlation purposes. From the pole positions given in Fig. 8, it is possible in principle to predict the average direction of the geomagnetic field for any part of Australia during any of the epochs represented. The directions observed in rocks of unknown or doubtful age may be compared with these theoretical values and a probable age allotted on this basis. Just as rock formations of a certain age may be identified by a fossil or fossil assemblage, they may also be identified by a certain direction of magnetization which arises from the geomagnetic pole being in a certain position relative to Australia during the time of deposition. Since the rate of polar movement relative to Australia is slow even on the geological time scale, the dating by this method is not as precise as that achieved by palaeontology, and although it ought to be possible to assign a rock group to a particular epoch, in general, it will not be possible to place it in one of the sub-divisions of that epoch. Consequently, the greatest application of this method is in unfossiliferous rock formations, notably in the Pre-Cambrian and in igneous rocks of younger date. Measurements are now being made to extend the curve in Fig. 8 back into the Pre-Cambrian, and when this is completed a method of the greatest assistance to Pre-Cambrian chronology will be available.

Although the Cainozoic basalts of Victoria can be dated for the most part with some accuracy, the dating of these basalts elsewhere in Australia is far from satisfactory. By comparing the directions of magnetization in these basalts against the "standard" directions found in Victoria, some information about their age may be provided. As an illustration of this method, directions observed in basalts from New South Wales, Tasmania and Queensland are used. Inclinations only are compared,

since the difference between the Older and Newer Volcanics is largely one of inclination. The co-latitudes for the collection area relative to the Newer and Older Volcanic poles are obtained by calculation (or graphically from Fig. 8) and the theoretical inclination is then obtained from equation (2). These values are listed against the observed inclinations in Table 2. The basalt of Berrima in New South Wales

TABLE 2

Comparison of Observed Inclinations with the "Standard" Values from Victoria

(Localities are marked in Fig. 1 and Table 3.)

Locality	Theoretical inclination deduced from the Victorian results		Observed Inclination
	From the Newer Volcanics	From the Older Volcanics	
A	49	65	43
B	56	70	71
C	62	74	78
D	62	74	80
E	62	74	69
F	62	74	54

(site B) has a large magnetic inclination (71°) very much steeper than that predicted for this region in Upper Pliocene and Quaternary times by results from the Newer Volcanics of Victoria (56°), but is similar to that anticipated for this region from the Older Volcanic data (70°) suggesting that it is comparable in age with the later. The basalt has been deeply dissected and duri-crusted, and a Lower Tertiary age is favoured on these grounds (David and Browne, 1950, p. 575). The palaeomagnetic and geological evidence is consistent, and the case for these basalts being of Lower Tertiary age is thereby greatly strengthened.

Near Wynyard in Tasmania (site C), a hillside excavation by Mr. M. R. Banks exposed a basalt beneath a Miocene limestone. The steep magnetic inclination in this indicates a Lower Tertiary age which is in agreement with the geological evidence.

The magnetic inclination in the basalt of Circular Head, Tasmania (site D), is steep, suggesting a Lower Tertiary age. Petrologically this basalt is similar to the Older Volcanics of Victoria (Edwards, 1940) and the field evidence, although not definite, is not inconsistent with a Lower Tertiary age.

The basalt of Skittle Balls Plain near the Great Lake, Tasmania (site F), has a moderate inclination indicating an Upper Tertiary or Quaternary age. This is consistent with the geological work of Voisey (1949) who regards these basalts as post-dating the main faulting in the region which Carey (1946) suggests in early Miocene.

The basalt at Clarence River, Tasmania (site E), gives a direction between the two predicted values. The geological indications of its age are also uncertain.

The basalts of Toowoomba, Queensland (site A), have an inclination appropriate to an Upper Tertiary or Quaternary age. This is contrary to the geological evidence which suggests that they are Lower Tertiary (David and Browne, 1950, p. 572).

At 4 sites (B, C, D, E), the palaeomagnetic and geological evidence is in agreement; at site A they are contradictory, and at site F both lines of evidence are indefinite. At each site only a small period of time is represented, so that errors due to the secular change of the Earth's magnetic field will arise. This may account for the result at site F. For a similar reason the palaeomagnetic evidence at site A may be in error, although in this case the geological dating is doubtful. The other four results are satisfactory, and it seems probable that a full palaeomagnetic survey of the Cainozoic basalts in the states of the Commonwealth (other than Victoria), when used in conjunction with geological evidence, will provide an improved basis for dating these formations.

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TABLE 3

Directions and Intensities of Magnetization, and Susceptibility

This table contains the primary data. Sites are designated as follows: Older Volcanics of Victoria OV1-15, Newer olcanics of Victoria NV1-32, and sites in other states A to F. D_i and I_i are the declinations and inclinations of ch individual specimen, D_s and I_s are the declinations and inclinations of the site mean directions. Reversed, rmal and mixed polarities are signified by R, N and X respectively. M is the remanent magnetic intensity in m.u. $\times 10^4$ per c.cm. χ is the magnetic susceptibility, being the ratio of the intensity of magnetization in e.m.u. 10^4 per c.cm. induced by an external field to the strength of that field, in this case 0·9 oersted.)

Site Number	Locality	Map	Grid Ref.		D_i	I_i	D_s	I_s	Polarity	M	χ
OV1	Jacob's Ck. Quarry, 8 m. S. of Walhalla	Moe 1″	438	400E	24	−72				19·5	0·4
					39	−48	33	−63	N	13·3	0·7
			313	900N	28	−70				25·9	0·6
OV2	S.E.C. Quarry, N. of Yallourn	Moe 1″	434	700E	353	−77				12·2	5·9
					157	+77	0	−75	X	7·2	6·0
			299	600N	12	−71				11·3	3·6
OV3	S.E.C. Quarry, N. of Yallourn	Moe 1″	434	900E	358	−80				8·9	3.2
					6	−81	345	−80	N	7·6	3·9
			299	500N	321	−77				9·9	2·8
OV4	True Blue Quarry, 1 m. WSW. of Mirboo North	Mirboo North 1″	412	500E	153	+65				35·6	10·1
					167	+66	165	+63	R	31·6	2·3
			265	100N	173	+58				37·3	0·7
OV5	Quarry on Berry's Ck. Rd., SW. of Mirboo North	Mirboo North 1″	407	500E	160	+75	149	+73	R	31·5	4·5
			263	500N	140	+71				57·6	3·5
OV6	Hillside Quarry, 2 m. SW. of Mirboo	Mirboo North 1″	417	600E	240	+42				10·7	4·6
					248	+52	244	+48	R	18·9	6·6
			253	700N	244	+49				10·3	6·6
OV7	Chalmers Hill Quarry, 3 m. E. of Leongatha	Korumburra 1″	399	900E	333	−82	1	+80	N	67·7	29·3
			255	200N	24	−76				63·8	20·8
OV8	Jindivick Quarry, N. of Warragul	Drouin 1″	391	600E	337	−63				14·9	5·0
					7	−66	0	−69	N	10·9	5·2
			309	400N	24	−73				23·1	8·2
OV9	Quarry at Drouin South	Drouin 1″	387	600E	325	−76				10·1	10·1
			294	700N	110	+80	324	−75	X	12·3	29·0
					160	+66				14·6	50·3
OV10	Bayview Quarry, Berwick	Cranbourne 1″	336	500E	59	−55				12·6	1·3
					59	−62	48	−56	N	10·4	3·8
			310	900N	30	−49				7·7	1·7
OV11	Second Quarry, nr. Berwick	Cranbourne 1″	336	300E	14	−66				22·4	16·5
					8	−61	6	−63	N	23·4	19·9
			310	800N	354	−61				37·4	18·8

OV12	Sea cliff nr. Pyramid rock	Woolamai 1″	325 800E 249 800N	166 189 205	+63 +69 +58	188	+64	R	12·5 5·7 14·7
OV13	Evans Quarry, Phillip Is.	Western Port 1″	325 100E 255 100N	281 19	−72 −79	319	−80	N	39·8 15·5
OV14	Sea cliff, Phillip Is.	Woolamai 1″	218 100E 252 600N	28 59 55	−69 −79 −57	47	−69	N	15·4 10·2 24·5
OV15	Sea cliff between Flinders and Cape Schanck	Sorrento 1″	290 200E 254 300N	80 58 133	−78 −67 −78	85	−76	N	8·4 11·3 4·4
NV1	Quarry nr. Turritable Falls, Mt. Macedon	Lancefield 1″	262 600E 385 500N	33 36	−42 −60	34	−51	N	6·1 7·6
NV2	Quarry nr. Forestry Commission's depot, Newport	Melbourne 1″	290 700E 234 700N	347 347	−58 −58	347	−58	N	10·5 12·7
NV3	Operating Quarry at Newport	Melbourne 1″	291 800E 333 300N	359 95	−66 −60	55	−71	N	7·5 77·4
NV4	Highfield Quarry, West Footscray	Melbourne 1″	288 900E 336 400N	332 349	−60 −59	340	−60	N	8·0 11·2
NV5	Lord's Quarry, Geelong Rd., Braybrook	Melbourne 1″	288 500E 335 800N	358 350	−56 −49	356	−52	N	6·8 15·3
NV6	Willis Quarry, Geelong Rd., Braybrook	Melbourne 1″	288 700E 335 900N	358 358	−56 −65	358	−61	N	10·1 24·7
NV7	Stanley Quarry, Market St., Braybrook	Melbourne 1″	288 200E 337 500N	8 9	−53 −55	9	−54	N	4·6 6·4
NV8	Regal Quarry, Duke St., Braybrook	Melbourne 1″	289 100E 341 700N	18 255	−49 +63	41	−59	N	15·8 5·0
NV9	McGrath's Quarry, Duke St., Braybrook	Melbourne 1″	289 200E 341 500N	338 352	−50 −60	343	−58	N	7·1 38·5
NV10	Albion Quarry, Sunshine	Melbourne 1″	286 200E 341 400N	359 11 15 4 8 0 3 20 4 18 9 6 10	−56 −64 −63 −63 −66 −52 −54 −52 −62 −58 −61 −60 −55	0·3	−61·8	N	3·9 2·9 3·8 3·5 3·5 0·6 0·6 0·6 0·6 1·6 0·6 0·8 0·6

710 nt.	Albion Quarry, Sunshine	Melbourne 1″	286 200E	17	−56	0·3	−61·8	N	0·6	0·6
			341 400N	10	−72				4·3	0·4
				354	−70				4·1	0·5
				4	−74				4·0	0·5
				354	−72				4·2	0·6
				351	−70				2·9	0·6
				338	−55				10·5	0·6
				339	−57				12·8	0·5
				358	−58				5·5	2·3
				347	−61				6·7	1·0
711	Fowler's Quarry, Keilor R., North Essendon	Sunbury 1″	291 800E	145	+50	157	+54	R	1·7	3·9
			345 700N	173	+57				2·3	5·7
712	Merri Ck. Quarry	Melbourne 1″	302 300E	203	+68	192	+74	R	6·9	4·8
			341 400N	183	+80				5·4	5·0
713	Paramount Quarry, Epping	Yan Yean 1″	304 800E	158	+51	158	+49	R	18·3	5·8
			353 100N	158	+46				20·5	6·7
714	Rock Quarry, Station St., Fairfield	Ringwood 1″	305 700E	173	+51	168	+49	R	88·6	20·0
			341 200N	164	+46				120·0	56·6
715	Adams's Quarry, Yarralea St., Alphington	Ringwood 1″	307 000E	144	+31	149·6	+34·9	R	13·5	7·1
			341 000N	150	+31				9·7	5·4
				150	+25				9·3	5·9
				150	+35				13·7	7·0
				142	+41				34·1	9·3
				158	+39				26·5	19·0
				136	+33				9·6	2·2
				134	+30				10·5	3·3
				143	+36				139·0	1·9
				150	+33				29·9	2·6
				150	+41				24·7	0·9
				148	+31				28·8	0·9
				137	+32				16·5	5·9
				143	+26				20·7	6·6
				143	+29				18·7	3·4
				150	+34				17·3	6·6
				133	+29				13·4	3·4
				143	+30				16·1	6·9
				147	+41				22·9	7·7
				147	+41				30·9	8·2
				147	+41				31·0	8·9
				152	+39				46·2	13·6
				157	+38				41·6	10·3
				161	+41				49·4	12·0
				152	+41				37·7	10·1
				161	+39				39·3	8·1
				151	+31				29·7	9·5
				153	+38				29·3	9·5
				156	+34				33·6	10·0
				156	+36				26·3	9·9
				154	+26				17·9	5·9
				158	+35				19·0	6·6
				156	+30				15·3	5·1
				178	+40				58·0	1·6

NV16	Werribee Quarry, Werribee	Melbourne 1″	263 900E 319 400N	177 177	+68 +57	177	+62	R	26·5 22·4
NV17	Reservoir Quarry, Bacchus Marsh	Ballan 1″	248 100E 351 800N	21 8 16	−57 −54 −62	15	−58	N	40·0 36·2 33·9
NV18	Dunnstown Quarry, Dunnstown	Ballarat 1″	203 400E 360 800N	150 158	+50 +73	152	+61	R	7·5 8·5
NV19	Council Quarry, Alfredton, Ballarat	Ballarat 1″	189 700E 365 300N	22 192	−48 +52	18	−50	X	9·4 14·2
NV20	Marnoch Vale Quarry, Geelong	Geelong 1″	240 300E 293 600N	182 33	+60 −60	16	−64	X	24·5 33·8
NV21	Minn's Quarry, Fyansford, Geelong	Geelong 1″	237 400E 295 000N	185 178	+61 +56	181	+59	R	6·9 7·9
NV22	Fyansford Quarry, Fyansford, Geelong	Geelong 1″	237 500E 295 600N	178 188	+58 +57	183	+57	R	5·7 25·4
NV23	Mobile Quarry, Fyansford, Geelong	Geelong 1″	237 700E 296 000N	148 192	+52 +53	170	+54	R	22·4 34·8
NV24	Pollacksford Quarry, Pollacksford Bridge	Geelong 1″	226 900E 295 800N	179 192	+56 +57	185	+57	R	13·5 26·7
NV25	Armytage Quarry, Armytage	Colac 1″	196 100E 278 400N	241 190	+85 +77	202	+82	R	3·9 4·2
NV26	Cobden Quarry, Cobden	Colac ¼″	597E 247N	56 76	−43 −19	68	−31	N	30·4 42·0
NV27	Framlingham Rd. Quarry, Framlingham	Panmure 1″	563 200E 276 100N	24 332	−75 −55	348	−67	N	30·5 19·0
NV28	Ararat Ck. Quarry, Ararat	Ballarat ¼″	593E 395N	213 194	+64 +71	205	+68	R	4·6 9·3
NV29	Barret's Quarry, Ararat	Ballarat ¼″	592E 396N	209 211	+58 +85	210	+71	R	9·0 6·4
NV30	Menzel's Quarry, Hamilton	Penshurst 1″	501 500E 342 100N	191 184	+43 +57	188	+50	R	16·4 17·7

31	Porter's Quarry, Heywood	Heywood 1″	459 000E 302 500N	211 222	+63 +60	217	+61	R	6·7 6·6	5·8 1·6
32	Portland Harbour Trust Quarry, Portland	Portland 1″	461 200E 268 200N	3 8 348 348	−53 −37 −45 −84	359	−56	N	21·9 5·4 3·8 4·5	2·6 0·2 3·3 1·9
	The Main Range Toowoomba, Queensland	Toowoomba 1″	506 700E 1578 000N and 506 100E 1579 100N	175 196 177 182 157 277	+35 +24 +26 +38 +53 +59	187	+43	R	1·2 1·3 6·1 23·6 1·1 5·1	5·6 3·3 10·1 15·4 3·5 3·5
	Road cutting on Hume Highway 3 m. NE. Berrima, New South Wales	Mittagong 1″	334 100E 741 100N	174 231	+73 +64	208	+71	R	45·6 15·2	12·2 4·4
	Seabrook Ck. E. of Wynyard, Tasmania	Devonport ¼″	379E 948N	44 53	−84 −73	50	−78	N	42·0 41·9	5·2 5·7
	Circular Head Quarry, Stanley, Tasmania	Smithton ¼″	335E 980N	10 90	−77 −76	50	−80	N	35·2 42·7	25·7 27·4
	Road cutting nr. Clarence R. and Bridge on Tarraleah Bronte Rd., Tasmania	Queenstown ¼″	438E 807N	16 324	−72 −63	344	−69	N	5·2 10·8	3·2 1·3
	Road cutting—Missing Link Rd., Skittle Balls Plain, Great Lake, Tasmania	Devonport ¼″	458E 830N	11 0	−57 −50	5	−54	N	9·4 5·9	1·3 2·3

2

MICROPLANKTON FROM AUSTRALIAN AND NEW GUINEA UPPER MESOZOIC SEDIMENTS

By Isabel C. Cookson* and A. Eisenack†

[Read 11 July 1957]

Abstract

The distribution of 75 species of fossil microplankton from Australian and New Guinea Upper Jurassic and Cretaceous deposits has been recorded and 12 new genera and 54 new species have been described. Some of the types have been identified with European species.

Upper Jurassic, Aptian, Albian, Cenomanian and Campanian microplankton assemblages have been distinguished.

Introduction

Three papers dealing partly (Cookson, 1953) or wholly (Deflandre and Cookson, 1955, and Cookson, 1956) with Australian fossil microplankton have already been published. The present and fourth contribution was to have been made in conjunction with Professor G. Deflandre of Paris, but pressure of work and other unforeseen circumstances rendered this impossible. Professor A. Eisenack then agreed to act as collaborator to assist with the taxonomic section of the paper.

This publication, unlike the earlier ones which dealt only with Tertiary and Cretaceous species, is concerned solely with Jurassic and Cretaceous types. Moreover, its scope has been enlarged to cover the Papuan region of New Guinea. The fossiliferous sediments comprising shales, siltstones, and calcarenites were chiefly supplied by West Australian Petroleum Pty. Ltd. (to be referred to hereafter as "Wapet") and by Island Exploration Co. Ltd. (to be referred to hereafter as "I.E.C.") from exploratory bores sunk respectively in the Exmouth Gulf and other areas of Western Australia and at Omati in Papua, New Guinea. Cretaceous samples provided by the Department of Geology, University of Queensland, the Queensland Geological Survey and the South Australian Department of Mines have also yielded species of microplankton that are both stratigraphically and morphologically interesting.

Some of these deposits have been reliably dated by means of ammonites, belemnites and foraminifera, the age of others is less certain. Some, for example the Gearle Siltstone of Western Australia, contain rich and varied microplankton assemblages, while in others, such as the Omati Well sample No. 30 (Table 1), one particular species predominates.

This work includes only a small proportion of the species present in the Mesozoic deposits examined. Many of these are new types, whilst those referable to European species have extended both the geographical and geological ranges of the particular forms.

For the isolation of the fossils the hydrofluoric acid—Schultz's solution—alkali treatment was adopted exclusively. The powdered and sieved rock was thoroughly boiled in hydrofluoric acid and allowed to stand over night, after which the residue

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was macerated in Schultz's solution (concentrated $HNO_3 + KClO_3$) for at least 12 hours and, after several washings with water, cleared in 10% sodium hydroxide. The final residue was mounted in Safranin glycerine jelly.

Location and Age of Sediments

Western Australia:

All samples from Western Australia were supplied by Wapet. Many of these were taken from formations dated by palaeontological means. The age of the Jurassic Dingo Siltstone is based on the ammonite studies of Dr. W. J. Arkell and the pelecypod studies of Dr. L. R. Cox. The dating of the Cretaceous formations is

FIG. 1.

based on foraminiferal correlations by Dr. M. F. Glaessner, Miss I. Crespin and Mr. D. J. Belford. Details of these correlations are given by McWhae et al. (1957 ms.).

1. Canning Basin. Broome No. 3 Artesian bore at 1405-37 ft. Age: Upper Jurassic—Tithonian according to Brunnschweiler (1954), Oxfordian to Lower Kimeridgian according to Teichert (1940, 1947).

2. Carnarvon Basin.
   (a) Exmouth Gulf Area.
      i. Rough Range. Well No. 1 is located 22°25′ S., 114°5′ E.
         Learmonth Formation. Wapet's Well No. 1 at 4376-79 ft. Age: Upper Jurassic.
         Muderong Shale. Wapet's Well No. 8 at 3863-83 ft. Age: Lower Cretaceous (Aptian).
         Windalia Radiolarite. Wapet's Well No. 4 at 3532-50 ft. Age: Lower Cretaceous (Aptian) and Lower Albian.
         Gearle Siltstone (lower part). Wapet's Well No. 7 at 2360-75 ft. and Well No. 1 at 2000 ft and 2750 ft. Age: Lower Cretaceous (Albian).
         Gearle Siltstone (upper part). Wapet's Well No. 8 at 1530-48 ft. and Well No. 5 at 1570 ft. Age: Upper Cretaceous (Cenomanian to Lower Turonian).
         Korojon Calcarenite. Wapet's Well No. 4 at 1380-86 ft. Age: Upper Cretaceous (Campanian to Lower Maestrichtian).
      ii. Cape Range. Well No. 2 is located 22°6′ S., 114°E.
         Dingo Siltstone (middle portion). Wapet's Well No. 1 at 6365-83 ft. Age: Middle Jurassic (Lower Callovian).
         Dingo Siltstone (upper portion). Wapet's Well No. 2 at 6032-50 ft. Age: Upper Jurassic (? Oxfordian).
         Dingo Siltstone (upper portion). Well No. 1 at 3825-40 ft. and Well No. 2 at 3970-91 ft. and 4509-27 ft. Age: Upper Jurassic (? Middle or Lower Kimeridgian).
   (b) Salt Marsh Area.
      "Grierson Member" of Birdrong Formation. Wapet's Grierson Well No. 3 at 1390-1400 ft. Age: Lower Cretaceous (Upper Neocomian to Lower Aptian).
   (c) South-Western Area.
      Probably "Grierson Member", Birdrong Formation. Meadow Station Artesian Bore No. 9. Age: Lower Cretaceous (? Upper Neocomian or Lower Aptian).

3. Perth Basin.
   (a) Gingin area.
      i. Seismic shot hole B.1, 4 m. N. of Gingin at 230 ft. Age: Probably Lower Cretaceous (Albian). See stratigraphical con- conclusions.
      ii. Seismic shot hole L.8 near Regan's Ford on Moore River at 240 ft. Age: Probably Lower Cretaceous (Albian). See stratigraphical conclusions.
      iii. Moora Bore at 86-170 ft. Age: Probably Lower Cretaceous. (Albian). See stratigraphical conclusions.

(b) Perth Metropolitan Area.
South Perth Formation.
i. Attadale Artesian bore at 809 and 899 ft. Age: Lower Cretaceous (? Aptian). See stratigraphical conclusions.
ii. Osborne Park (King Edward Street) bore at 265-95 ft. Age: Probably Lower Cretaceous (Albian). See stratigraphical con-conclusions.
iii. Subiaco Artesian bore at 358 ft. Age: ? Upper Cretaceous (Cenomanian). See stratigraphical conclusions.

South Australia:

Cootabarlow, near Lake Frome. Grey siltstones from Bore No. 2 at 581 ft. and 1354 ft. Age: Lower Cretaceous (Albian and Aptian respectively). See stratigraphical conclusions.

New South Wales:

Onepah Station near Tibooburra. Soft fine-grained grey sandstone dug from a well at an unspecified depth. Age: Lower Cretaceous (Albian), H. O. Fletcher and E. J. Kenny in Deflandre and Cookson (1955, pp. 246, 294). See stratigraphical conclusions.

Queensland:

Roma Series, North Queensland. Calcareous deposit from a well on Batavia Downs Station. Cape York Peninsula at 45-49 ft., within 20 yds. of Main Road, 24 m. S. of Moreton's Telegraph station. Age: Lower Cretaceous (Aptian).

Styx River Series. Carbonaceous shale from Queensland Geological Survey's Bore 21 at 327 ft. sunk in the Tooloombah Creek area. Styx Coalfield about 80 m. N. of Rockhampton. Age: Lower Cretaceous (Albian), Walkom (1919).

New Guinea:

Omati River District, Western Papua. Carbonaceous deposits from I.E.C.'s Well No. 1. Age: Upper Jurassic to Lower Cretaceous (Albian-Aptian) as determined by I.E.C.

Era River District, Papua. Australasian Petroleum Company's Wana Well sample 451. Age: Upper Jurassic.

Description of Types

CLASS DINOFLAGELLATA

Family GYMNODINIDAE

Genus **Gymnodinium** Stein

Gymnodinium crystallinum Defl.

(Pl. I, figs. 1, 2, 5)

Gymnodinium crystallinum Defl., 1938. *Trav. Stat. Zool. Wimereux,* 13; 165, Pl. V, fig. 1.

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 1 at 3825-40 ft. and Well No. 2 at 3970-91 ft.; Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.; Omati, Papua, I.E.C. Well

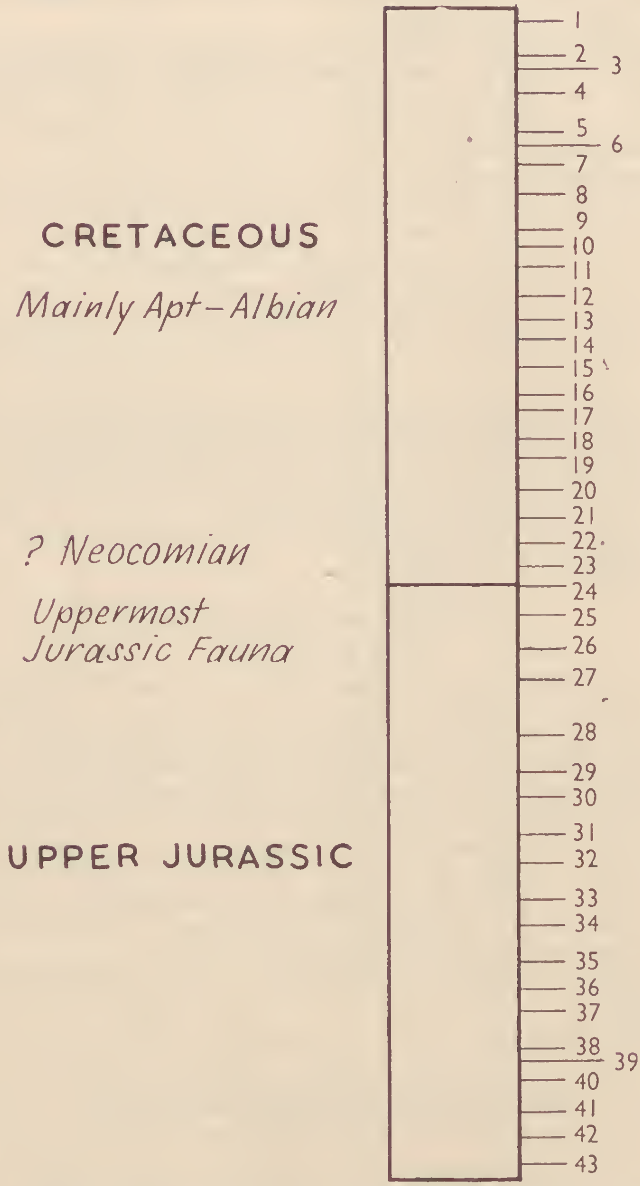


Fig. 2.—Diagram showing the Relative Stratigraphic Positions of Mesozoic Samples from Omati, Papua.

No. 1, Samples 24, 35 (Table 1). Middle Jurassic: Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1 at 6365-83 ft.

Description. Since many of the species of Mesozoic microplankton are known, as yet, from only a relatively small number of individuals, a wide degree of variation has been allowed throughout this work when referring southern forms to northern species, and this applies particularly to the present record of *Gymnodinium crystallinum* in the Australian area.

The example from Broome, W.A. (Pl. I, fig. 1), agrees exactly with the holotype from the French Oxfordian. The specimens obtained from the upper portion of the Dingo Siltstone (Cape Range), of which the form shown on Pl. I, fig. 2 is a representative, on the contrary, vary more or less considerably from it and eventually may prove to represent a distinct species. They are more elongated and considerably larger than the French specimens (142-166 μ long and 109-147 μ wide as against 65-92 μ x 58-85 μ) and have a distinct and very characteristic apical prominence.

The forms occurring in the middle portion of the Dingo Siltstone (Pl. I, fig. 5) are smaller (81-90 μ x 76-85 μ) and more comparable in size to the French examples. They appear to have been a much thicker and more substantial type than *Gymnodinium parvimarginatum* sp. nov. from the Broome bore which they approach in the width of the margin surrounding the capsule.

With few exceptions a large pylome has been present in the epitheca of all the Australian specimens of *G. crystallinum.*

Gymnodinium luridum Defl.

(Pl. I, figs. 3, 4)

Gymnodinium luridum Defl. *Trav. Stat. Zool. Wimereux,* 13; 166, Pl. V, fig. 4.

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper part), W. A., Wapet's Cape Range Well No. 1 at 3825-90 ft. and Well No. 2 at 3970-91 ft. and 6032-60 ft.; Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.

Description. The Western Australian specimens agree closely with the original description of *Gymnodinium luridum* from the French Oxfordian and, like the French paratypes, are frequently broader than long.

Thin lines which suggest the limits of plates are evident on the dorsal surface of the hypotheca in some examples while the position of the longitudinal furrow is indicated, occasionally, by two narrow plates that run from the apex to the antapex of the ventral surface (Pl. I, fig. 3).

A large pylome (not noted in the French samples) has always been present on the epitheca.

Dimensions. Fig. 3—105 μ x 118 μ; Fig. 4—100 μ x 90 μ.

Gymnodinium parvimarginatum sp. nov.

(Pl. I, fig. 6; holotype)

Age and occurrence. Upper Jurassic: Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.

Description. Theca almost circular to broadly oval in outline, divided somewhat unequally by a straight and narrow transverse furrow into a rather shorter and occasionally slightly pointed epitheca and a longer rounded hypotheca. Inner capsule*

* Eisenack (1954) prefers the use of the term "capsule" to "cyst" as adopted by Deflandre (1938, p. 165).

not entirely filling the thin membrane but surrounded by a narrow margin *c.* 5 μ wide.

As in the Australian species of *G. crystallinum* and *G. luridum*, a relatively large pylome extends vertically from the transverse girdle almost to the apex of the epitheca.

Dimensions. Type 90 μ x 90 μ. Range 76-100 μ x 76-100 μ.

Comments. This species is distinguished by the almost circular outline, narrow margin (*c.* 5 μ), the width of which, in the Australian and New Guinea species of *G. crystallinum* is *c.* 5-15 μ and in *G. luridum* *c.* 7-10 μ, and its flatter form.

Gymnodinium attadalense sp. nov.

(Pl. I, fig. 7; holotype)

Age and occurrence. Lower Cretaceous (? Aptian): South Perth Formation, W.A., Attadale Bore at 809 ft.

Description. The test has a rather squarish outline with almost straight to convex sides and is divided unequally by a shallow transverse girdle into a slightly shorter and broader epitheca and a longer and somewhat pointed hypotheca.

The capsule follows the outline of the test but does not fill its cavity, a margin of about 11 μ being left around it. In the type the antapex of the capsule seems to be open, as does the membrane of the test directly opposite to it. However, this feature has not been evident in the three other examples of *G. attadalense* in the present collection. The outer membrane and membrane of the capsule are very faintly granular to smooth. A large pylome is developed in the epitheca.

Dimensions. Type 81 μ x 81 μ, capsule 59 μ x 59 μ.

Comments. G. attadalense is of the same general type as the Jurassic species *G. crystallinum*, *G. luridum* and *G. parvimarginatum*, but differs from all in the shape of the test.

These four species, in having flattened shells with thin margins, central capsules and conspicuous pylomes are distinct from such true fossil *Gymnodinia* as *Gymnodinium cretaceum* Defl., *G. heterecostatum* Defl. and *G. nelsonense* Cookson. It seems probable, therefore, that eventually they will be removed from the genus *Gymnodinium*. See Appendix 1.

Gymnodinium westralium sp. nov.

(Pl. I, fig. 9; holotype)

Gymnodinium cf. *heterocostatum* Defl. and Cookson 1955. *Aust. J. Mar. Freshw. Res.*, 6; 248, Pl. I, fig. 7.

Age and occurrence. Upper Cretaceous (Campanian and Lower Maestrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1350-88 ft. Upper Cretaceous (? Senonian Teichert 1947): Molecap Greensand, Gingin, W.A. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 8 at 1530-48 ft. and Well No. 5 at 1570 ft.

Description. Shell biconical, epitheca and hypotheca approximately the same size, the hypotheca being the more rounded of the two, separated by a narrow and apparently shallow transverse furrow; a longitudinal furrow is not apparent.

The shell membrane is ornamented with numerous longitudinal ridges that converge from the furrow to the apex and antapex respectively. In the specimens from the Gearle Siltstone the membrane between the ridges is smooth, in those

from the Korojon Calcarenite it has been regularly and longitudinally punctate. However, more examples will be needed to determine whether this feature is of primary or secondary origin.

Dimensions. Type 47 μ x 28 μ, other specimens 38 μ x 25 μ and 71 μ x 38 μ. Examples from Molecap Greensand 58-61 μ x 48-54 μ.

Comments. In shape, *G. westralian* resembles *G. cretaceum* Defl. from the French Upper Cretaceous (Senonian), but differs from this species in its larger size and narrower furrow. The two specimens from Gingin, doubtfully compared with *G. heterocostatum* Defl. by Deflandre and Cookson 1955, agree with *G. westralium* in shape, approximate size, and in having ridges of one size only.

Gymnodinium nelsonense Cookson

(Pl. I, fig. 8)

Gymnodinium nelsonense Cookson 1956. *Aust. J. Mar. Fresh. Res.*, 7; 183, Pl. I, fig. 10.

Age and occurrence. Upper Cretaceous (Campanian and Lower Maestrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4, at 1350-88 ft.

Description. Two examples from the Korojon Calcarenite are referable to *G. nelsonense* originally described from the Upper Cretaceous portion of the Nelson Bore, Victoria. In the figured specimens, longitudinal ridges as well as folds are suggested.

Family Deflandreidae

Genus **Deflandrea** Eisenack

Deflandrea cincta sp. nov.

(Pl. IV, figs. 1-3; holotype, fig. 3)

Age and occurrence. Lower Cretaceous (Upper Neocomian or Lower Aptian): Probably "Grierson Member", Birdrong Formation, W.A., Meadow Station Bore No. 9.

Description. Theca elongated, clearly separated into an epitheca and hypotheca by a strongly marked transverse girdle, a short longitudinal furrow is situated on the ventral surface of the hypotheca. The epitheca is convex laterally and narrows rather abruptly towards a short terminal truncated horn with a small central projection. The hypotheca is slightly narrower than the epitheca and posteriorly is prolonged on one side into a short, broad, sharply-pointed horn and on the other into a broadly conical expansion. The external membrane is somewhat coarsely granular.

The capsule is smooth, broadly oval, and usually extends laterally to the outer membrane.

Dimensions. Type—theca 88 μ x 52 μ; capsule 55 μ x 40 μ. Range—theca 81-118 μ x 52-66 μ; capsule 52-66 μ x 45-57 μ.

Comments. Deflandrea cincta although differing from the genotype *D. phosphoritica* Eis. and other species in having a prominent transverse girdle, is, by its shape, absence of plates and in the presence of an internal capsule, clearly a member of the genus *Deflandrea*. The development of both transverse and longitudinal furrows completely confirms Eisenack's reference (1938) of *D. phosphoritica* to the Dinoflagellata, although such features are not represented in that species. *D. cincta* is the dominant type in the microplankton assemblage of the Meadow Bore deposit.

Deflandrea acuminata sp. nov.

(Pl. IV, figs. 5-8; holotype, fig. 5)

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (Upper), W.A., Wapet's Rough Range Well No. 5 at 1570 ft. and Wapet's Rough Range Well No. 8 at 1530-48 ft. ? Upper Cretaceous (Cenomanian): Subiaco, W.A., Water Bore at 358 ft.

Description. Theca broadly oval with convex sides or almost spherical, apex acuminate, antapex obliquely truncate, prolonged on one side into a small pointed horn. A transverse girdle is perceptible at the lateral margins of the theca.

The capsule, which is always separated from the membrane of the theca by a relatively wide space is approximately spherical, and slightly pointed on the side directed towards the apex of the theca.

Both the internal and external membranes are smooth. A rounded or polygonal pylome is present above the apex of the capsule.

Dimensions. Type—theca 85 μ x 62 μ; capsule 48 μ x 48 μ. Range—theca 66-99 μ x 52-62 μ; capsule 38-47 μ x 38-47 μ.

Deflandrea pellucida sp. nov.

(Pl. IV, fig. 9)

Deflandrea bakeri f. *pellucida* Defl. and Cookson 1955. *Aust. J. Mar. Freshw. Res.,* 6; 251, Pl. IV, fig. 3 (holotype).

Age and occurrence. Paleocene to Lower Eocene: Nelson Bore, Vic., at 3874 ft. (Holotype); Pebble Point Formation, Vic. Upper Cretaceous (Campanian to Lower Maestrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1380-88 ft.

Description. Theca elongate oval with convex sides that narrow anteriorly towards an acuminate apex and posteriorly towards an obliquely truncate or slightly concave antapex. A transverse girdle is either faintly indicated or absent, a somewhat polygonal aperture is present in the anterior portion of the epitheca.

The capsule, which is broader than long and flattened in the antero-posterior plane, invariably extends laterally to the outer membrane. The membrane of the theca is finely granular, that of the capsule is smooth.

Dimensions. Type—theca 118 μ x 77 μ; capsule 67 μ x 74 μ. Western Australian examples—theca 109-128 μ x 76-81 μ; capsule 57-66 μ x 71-78 μ.

Comments. The organism here raised to specific rank, was originally described as a form of *Deflandrea bakeri* Defl. and Cookson, a Victorian Lower Tertiary species. Recently specimens identical in every way with *D. bakeri* forma *pellucida* were isolated from a sample of the Korojon Calcarenite (Campanian to Lower Maestrichtian) in NW. Western Australia. The constancy of their agreement with the Victorian examples when taken in conjunction with their wide geographical and geological separation, suggests specific rather than varietal rank for this type. Moreover *D. bakeri* has a more elongate form than *D. pellucida,* a more coarsely sculptured theca, and the internal capsule does not extend to the lateral margins. *D. bakeri* has not as yet been found in deposits of Cretaceous age.

Deflandrea korojonensis sp. nov.

(Pl. IV, figs. 10, 11; holotype, fig. 10)

Age and occurrence. Upper Cretaceous (Campanian to Lower Maestrichtian): Korojon Calcarenite, Wapet's Rough Range Well No. 4 at 1380-86 ft.

Description. Theca rather variable in outline, typically somewhat quadrangular, with convex sides which become concave beneath the broadly rounded or bracket-shaped apex and narrow gradually towards a more or less truncate antapex, sometimes one side is prolonged as an abbreviated horn; a transverse furrow is not indicated.

The capsule fills the theca laterally and is usually broader than long; a slightly polygonal pylome is present near its anterior end. The membrane of the theca is smooth, that of the capsule faintly granular.

Dimensions. Type—theca 71 μ x 52 μ; capsule 38 μ x 50 μ. Range—theca 61-80 μ x 38-53 μ; capsule 32-42 μ x 36-50 μ.

Deflandrea parva sp. nov.

(Pl. IV, figs. 12, 13; holotype, fig. 12)

Age and occurrence. ? Lower Cretaceous (Albian): North of Gingin, W.A., Siltstone from Seismic shot hole B.1 at 230 ft. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), Rough Range Well No. 8 at 1530-48 ft.

Description. Theca smooth, roughly five-sided much as in *D. phosphoritica* or more rounded and elliptical in outline, apex pointed, antapex with a short-pointed horn on one side (Pl. III, fig. 13) or truncate. Transverse furrow rather well developed. Capsule oval, faintly granular not filling the theca laterally.

Dimensions. Type—theca 57 μ x 38 μ; capsule 38 μ x 30 μ. Range—theca 48-57 μ x 33-38 μ.

Deflandrea serratula sp. nov.

(Pl. IV, fig. 4; holotype)

Age and occurrence. Upper Cretaceous (Campanian to Lower Maestrichtian); Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1380-86 ft.

Description. The theca is somewhat longer than broad and is widest in the region of the well defined transverse girdle, narrowing from thence towards a prominent apical region which is shaped like a pointed arch, and towards a more or less concave antapex on one side of which is a short pointed horn. A broad longitudinal furrow is present on the hypotheca, but it does not extend to the antapex.

The outer membrane is thin, transparent and rather coarsely granular, but on both sides of the epitheca, between the girdle and the distal limits of the apical arch, it is finely serrated.

The capsule is large in proportion to the size of the theca and extends to the lateral margins. In the type, the position of the future pylome is clearly indicated.

Dimensions. Type—theca 73 μ x 48 μ; capsule 38 μ x 47 μ; pylome 14 μ across.

Genus **Wetzeliella** Eisenack

Wetzeliella irregularis sp. nov.

(Pl. X, figs. 1, 2; holotype, fig. 1)

Age and occurrence. Upper Jurassic: Dingo Siltstone, W.A., Wapet's Cape Range Well No. 2 at 3970-3991 ft.

Description. Shell roughly four-sided with rather abbreviated apical and antapical horns and two more strongly defined lateral horns; the membrane is provided

with somewhat distantly placed bifurcate processes. At the antapex in the type, the processes have fused more or less giving it a somewhat lobed outline.

The capsule is nearly spherical and completely fills the shell, a large pylome is situated near the apex. In two of the four specimens (Pl. X, fig. 2), a "girdle" is faintly indicated.

Dimensions. Holotype—overall length 119 μ (apical horn is turned back), width 133 μ; capsule 85 μ x 81 μ. Paratype (Pl. X, fig. 2)—overall length 107 μ, width 114 μ; capsule 76 μ x 76 μ.

Comments. This form is referred to *Wetzeliella* on account of its squarish outline, the development of four horns, the type of ornament and the presence of an internal capsule. It differs from all other species of the genus in the irregular form of the horns and ornament. *W. irregularis* is to some extent like *Wetzeliella ? neocomica* Gocht (1957) from the Upper Hauterivian of Emsland, Germany. Hitherto *Wetzeliella* has not been known from the Jurassic.

Family GONYAULACIDAE

Genus **Gonyaulax** Diesing

Gonyaulax ambigua Defl.

(Pl. III, fig. 1)

Gonyaulax ambigua Deflandre 1941. *Acad. Sci. Inst. Fr.*, Mem. 6; 14, Pl. IV, fig. 6.

Age and occurrence. Upper Jurassic, Dingo Siltstone (Upper), W.A., Wapet's Cape Range Well No. 1 at 3825-40 ft. and Well No. 2 at 3970-91 ft. and 4509-27 ft.; Omati, Papua, I.E.C.'s Well No. 1, samples 24, 27, 36 (Table 1).

Description. Theca broadly oval to almost spherical, epitheca and hypotheca nearly equal, separated by a shallow transverse furrow with low borders; plates delimited by low and narrow membranes. Plates smooth or very faintly granular. The appearance of a short horn is suggested by the projection of the membranes between the apical plates. The exact tabulation has not been determined.

Dimensions. Western Australian examples—81-128 μ x 71-109 μ; New Guinea examples—71-99 μ x 57-71 μ.

Comments. In spite of the fact that the tabulation could not be exactly determined the general features of the Australian specimens clearly indicate identity with *Gonyaulax ambigua*. This species was originally described from the Kimeridgian schists of Orbagnoux, France. Recently the same species has been recorded by Downie (1957) from Kimeridge in England. The Australian examples are considerably larger than the European forms.

Gonyaulax jurassica Defl.

(Pl. II, figs. 9, 10)

Gonyaulax jurassica Deflandre 1938. *C.R. Acad. Sci.* 206; 688, Fig. 2.

Age and occurrence. Upper Jurassic: Dingo Siltstone, W.A., Wapet's Cape Range Well No. 2 at 3970-91 ft. and 6032-60 ft., and Well No. 1 at 3825-40 ft.; Learmonth Formation, W.A., Wapet's Rough Range Well No. 1 at 4376-79 ft.; Broome, Artesian Bore No. 3 at 1405-27 ft. Middle Jurassic: Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1 at 7825-41 ft.

Description. The dimensions, tabulation and ornamentation of the Australian specimens are conformable with those of the holotype and paratypes described by Deflandre (1938) from the French Oxfordian.

Comments. G. jurassica has been recorded by Valensi (1953) from the Bathonian of Lessart, France; by Deflandre (1938, p. 150) from the Dogger of East Prussia and the Oxfordian of Villers-sur-Mer, France; and by Downie (1957) from the Kimeridgian of Kimeridge, England.

Gonyaulax eisenacki Deflandre subspecies **oligodentata** nov. sub. sp.

Gonyaulax eisenacki Deflandre, 1938. *Trav. Stat. Wimeraux* 13; 171, Pl. VI, fig. 7.

Age and occurrence. Upper Jurassic: Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.

Description. Two specimens agree so well in shape, size and tabulation with *G. eisenacki* that they can be referred without doubt to this species. However, they differ from it in the smooth or only minutely and sparingly denticulated sutures of the plates and transverse furrow, and for this reason have been separated as a subspecies of the type. In the antapical region the outer membrane reaches considerably beyond the end of the body where, supported by 4 long processes, it forms a hollow cylinder.

Dimensions. Type—96 μ x 57 μ; second specimen—100 μ x 67 μ.

Comments. Gonyaulax eisenacki has been recorded by Deflandre (1938, p. 150) from the Dogger of East Prussia and the Oxfordian of France. An imperfectly preserved specimen from the Bathonian of Lessart, France, has been compared with *G.eisenacki* of Valensi (1953).

Gonyaulax scotti sp. nov.

(Pl. II, figs. 5, 6; holotype, fig. 5.)

Age and occurrence. Upper Jurassic: Dingo Siltstone, Wapet's Cape Range Well No. 2 at 3970-91 ft. and Well No. 1 at 3825-40 ft.

Description. Theca variable in shape but mostly oval; epitheca dome-shaped with a sharply delimited horn, hypotheca more rounded. Wall of theca thick, prolonged at intervals into short, blunt processes and ornamented, especially in the antapical region, by rather delicate processes that are sometimes free but more often confluent forming a loosely constructed or homogeneous membrane. The transverse girdle is narrow and generally obscured by the superficial membrane as frequently are the outlines of the plates.

The tabulation has not been exactly determined but in general conforms to that characterizing the genus *Gonyaulax*.

Dimensions. Type—147 μ x 119 μ. Range—118-156 μ x 114-119 μ. Apical horn 21-24 μ long.

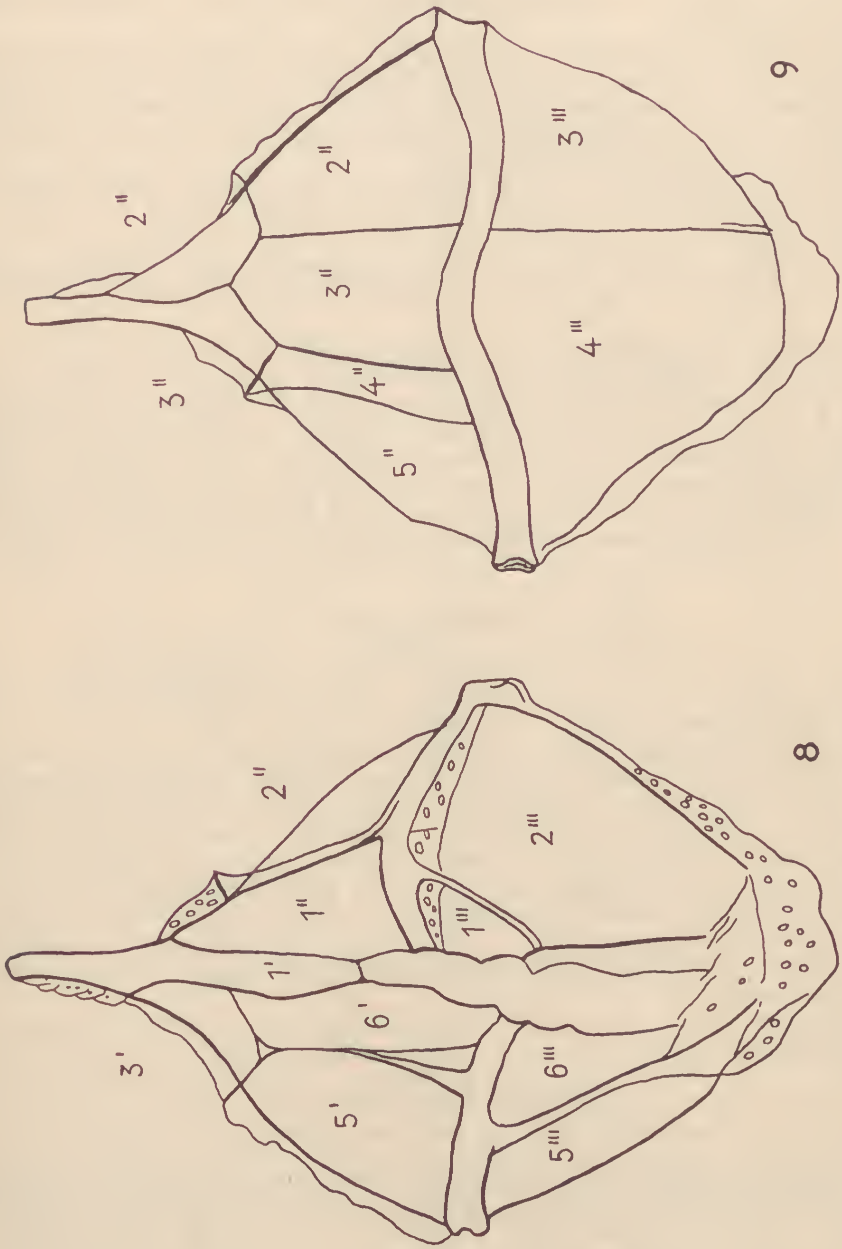
Comments. In its general features *Gonyaulax scotti* agrees with the European Upper Jurassic species *G. cladophora* Defl. but differs in its rather more elongated form and more complex type of ornamentation. In *G. cladophora* the spiny outgrowths delimiting the plates and furrow are free from one another, whereas in *G. scotti* they are usually fused distally forming a delicate membrane.

The species is named after Mr. D. H. Scott, late Exploration Superintendent of Wapet.

Gonyaulax perforans

(Pl. II, figs. 1-4, 7, 8; holotype, fig. 1. Figs. 8, 9)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C.'s Well No. 1, sample 31 (Fig. 2).



FIGS. 8-9.—*Gonyaulax perforans* sp. nov. ventral and dorsal surfaces. Omati Bore, Papua, × 680.

Description. Theca longer than broad with a distinctly helicoid girdle. Epitheca conical surmounted by a well-developed bluntly-pointed horn. Hypotheca more rounded than epitheca.

Wall of theca thin, smooth, ornamented to a varying degree by the thin perforated membranes that border the plates and, more especially, the transverse furrow which is frequently almost hidden by a lacy network. A similar ornament is usually well developed in the mid-dorsal region of the hypotheca from which it extends as a prominent projection beyond the antapex.

The longitudinal furrow which passes into the epitheca and to the antapex is unornamented except at the antapex. The plate 1′ which reaches to the horn is especially thin.

In a few specimens (Pl. II, figs. 3, 4) which possibly represent a distinct species, the external ornament is more strongly developed, especially in the region of the girdle.

Dimensions. Type—168 μ x 109 μ. Range—136-168 μ x 93-109 μ.

Comments. Gonyaulax perforans is clearly related to *G. scotti* but differs in its shape, thinner wall, the more prominent antapical boss and the structure of the external ornament. In *G. scotti* the processes of which the membranes ornamenting the theca are constructed, although fused distally, are often individually visible (Pl. II, fig. 5) whereas in *G. perforans* the membranes have a more continuous texture with more or less numerous perforations of various sizes. Furthermore the limits of the plates are more heavily ornamented in *G. scotti* than in *G. perforans.*

Gonyaulax muderongensis sp. nov.

(Pl. III, figs. 3, 4; holotype, fig. 3. Fig. 15)

Age and occurrence. Lower Cretaceous (Aptian): Muderong Shale, W.A., Wapet's Rough Range Well No. 1 at 3863-83 ft.

Description. Theca biconical to oval with a rather long, stiff horn that is closed by a "lid" having a short median terminal projection (Fig. 15); epitheca and hypotheca nearly equal. Girdle narrow, helicoid; longitudinal furrow short, extending somewhat into the epitheca and not reaching the antapex. Plates numerous, slightly granular provided with irregularly distributed short, blunt spiny outgrowths and worm-like surface ridges, sutures thickened. The girdle is bordered on both sides by short regularly arranged processes which are the terminations of the ridges on the surface of the plates adjoining it (Pl. III, fig. 4). Wall of theca moderately thick sometimes with an outer thin transparent ornament formed by the coalescence of fine processes.

Dimensions. Type—147 μ x 105 μ. Range—109-147 μ x 94-105 μ. Apical horn 16-25 μ long.

Gonyaulax edwardsi sp. nov.

(Pl. III, figs. 5, 6; holotype, fig. 6. Fig. 7)

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 5 at 1570 ft. ? Upper Cretaceous (Cenomanian): Subiaco, W.A., Artesian bore at 358 ft. Probably Lower Cretaceous (Albian): Gingin, W.A., Seismic shot holes B.2 at 230 ft. and L.8 at 240 ft. Perth, W.A., King Edward Street Bore at 265-95 ft. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough

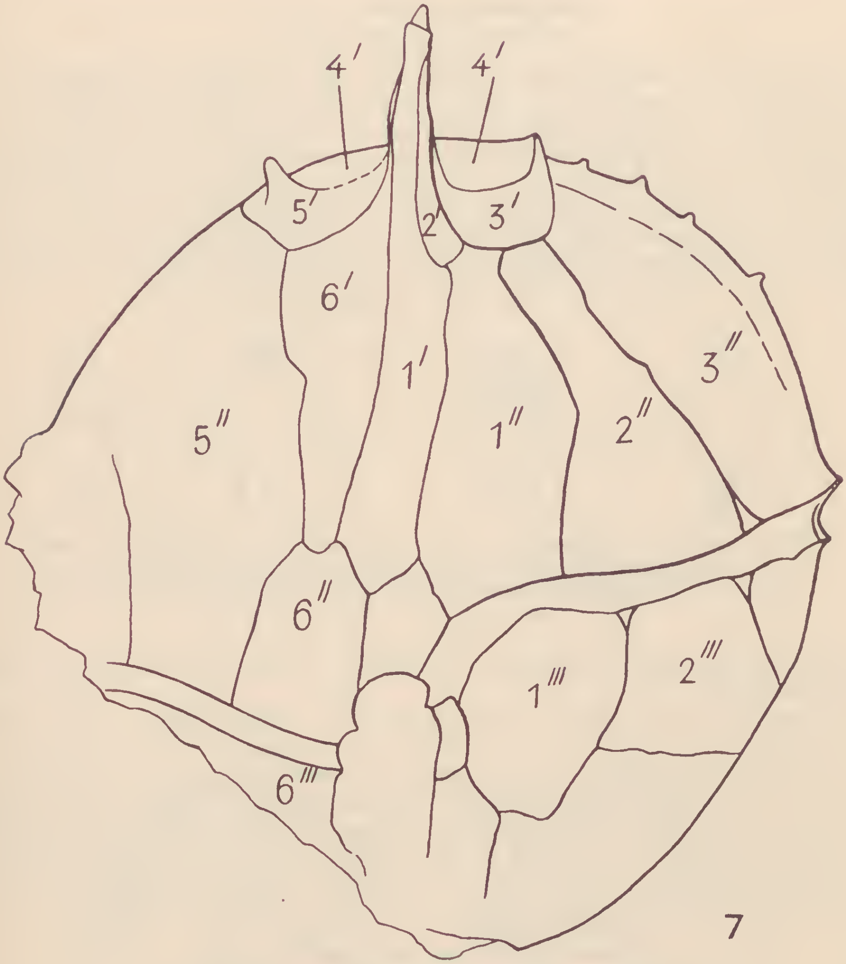


FIG. 7.—*Gonyaulax edwardsi* sp. nov. ventral surface.
Gearle Siltstone (lower part), W.A. × *c.* 870.

Range Well No. 1 at 2000 and 2750 ft.; Styx River Series, Queensland, Queensland Geological Survey Bore No. 21 at 327 ft.

Description. Shell nearly spherical, thick walled. Epitheca with a long, stiff, pointed and sometimes curved horn. Girdle helicoid, narrow with low borders; longitudinal furrow broad. Plates finely granular, the inner surface of girdle sometimes more coarsely granular than the plates. Sutures of the plates with low, thin ledges which often bear a few rather broad, pointed spines especially in the apical and antapical regions.

This species is named after Dr. A. B. Edwards, Officer-in-Charge, Mineragraphic Investigations, C.S.I.R.O., who has forwarded this work.

Dimensions. Type—143 μ x 125 μ overall.

Gonyaulax serrata sp. nov.

(Pl. III, fig. 2. Figs. 12-14)

Age and occurrence. Upper Jurassic to possibly Lower Cretaceous (Neocomian); Omati, Papua, I.E.C.'s Well No. 1, samples 19, 20, 25 (Fig. 2).

Description. All the available specimens are flattened and in consequence polygonal in outline. The plates of both epitheca and hypotheca are relatively large and the transverse girdle is helicoid; the longitudinal furrow extends to the antapical plate. The epitheca is terminated by a very short conical process which is covered with spiny projections (Figs. 12-14) and the sutures of the plates and margins of the furrow are ornamented with rather broad comb-like ledges, the teeth of which are either rounded, knob-like or occasionally slightly bifurcate.

12 13 14 15

FIGS. 12-14.—*Gonyaulax serrata* sp. nov. apical horns of three specimens showing the variation in shape and ornamentation. Omati Bore, Papua, × *c.* 625.
FIG. 15.—*Gonyaulax muderongensis* sp. nov. terminal portion of apical horn. Muderong Shale, W.A., × *c.* 625.

The exact tabulation could not be determined. However, *G. serrata* is a readily recognizable form.

Dimensions. Type—109 μ x 100 μ. Another specimen 100 μ x 94 μ; spines *c.* 2·5-6 μ long.

Comments. Gonyaulax serrata seems to be closely related to *G. cladophora* Defl. from the French Oxfordian. However, it differs from that species in the simpler form and more even length of the spines ornamenting the shell, and in the form of the apical prominence. According to the original diagnosis, *G. cladophora* always has a distinct tubular apical horn. In *G. serrata*, on the other hand, only a short blunt apical prominence surmounted by a few short spines is developed.

Gonyaulax hyalodermopsis sp. nov.

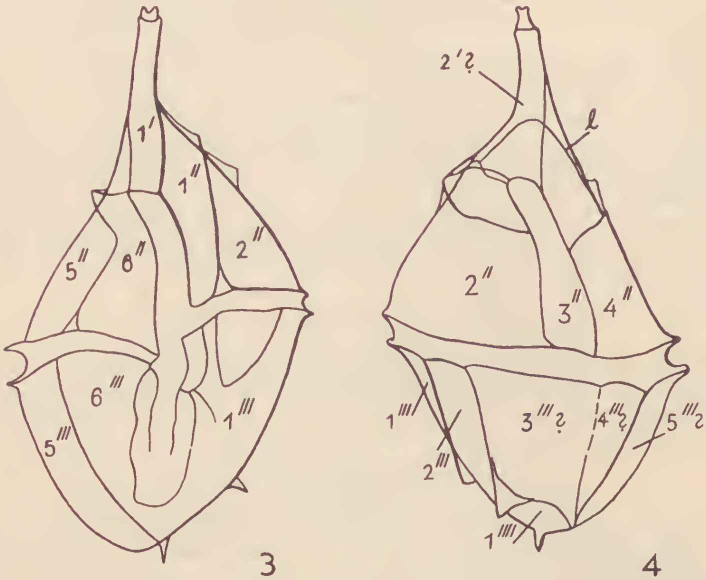
(Holotype—Pl. III, figs. 11, 12. Figs. 5, 6)

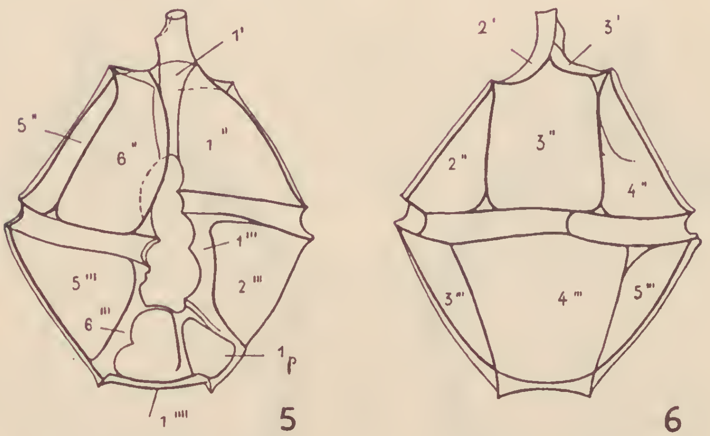
Age and occurrence. Lower Cretaceous (Aptian or older): South Perth Formation, W.A., Attadale Artesian Bore at 809 ft. Lower Cretaceous (Upper Neocomian or Lower Aptian): "Grierson Member", Birdrong Formation, W.A., Meadow Station Artesian Bore No. 9.

Description. Theca thin, transparent and smooth, obtusely biconical to slightly oval. Epitheca and hypotheca nearly equal. Apex surmounted by a short cylindrical horn with a pointed apex. Transverse girdle shallow, distinctly helicoid, longitudinal furrow broad. Sutures with smooth, thin and shallow ledges. Dorsal plates very large. The tabulation is shown in Figs. 5, 6.

Dimensions. Type—73 μ x 55 μ overall, horn 9 μ; 62 μ x 47 μ, horn 9 μ.

Comments. In size and shape *G. hyalodermopsis* approaches *Palaeoperidinium hyalodermum* Defl. (1942). However, it cannot be identified with the French Kimeridgian species on account of the imperfect preservation of the type.





FIGS. 3-4.—*Gonyaulax apionsis* sp. nov. ventral and dorsal surfaces. Cootabarlow Bore, S.A., × 680.
FIGS. 5-6.—*Gonyaulax hyalodermopsis* sp. nov. ventral and dorsal surfaces. South Perth Formation, W.A., × 650.

Gonyaulax apionis sp. nov.

(Pl. III, fig. 7; holotype. Figs. 3, 4)

Age and occurrence. Lower Cretaceous (Albian): Cootabarlow, S.A., Bore No. 2 at 600 ft.

Description. Shell smooth nearly twice as long as broad, epitheca long, conical, surmounted by a long, stiff horn which is closed at one end by a "lid" with a short central projection. The girdle is strongly helicoid and bordered by low but rather sharp ledges. The hypotheca is more dome-shaped and the antapical plate is square with 4 small pointed projections at the corners. The ledges bordering the plate are smooth and low.

In the type a long narrow pylome stretches from the base of the horn to the girdle (plate 3″). The tabulation, though rather distinct, cannot be given in full detail; it appears to be simple.

Dimensions. Type—105 μ x 57 μ, horn 20 μ. A paratype—114 μ x 71 μ, horn 24 μ.

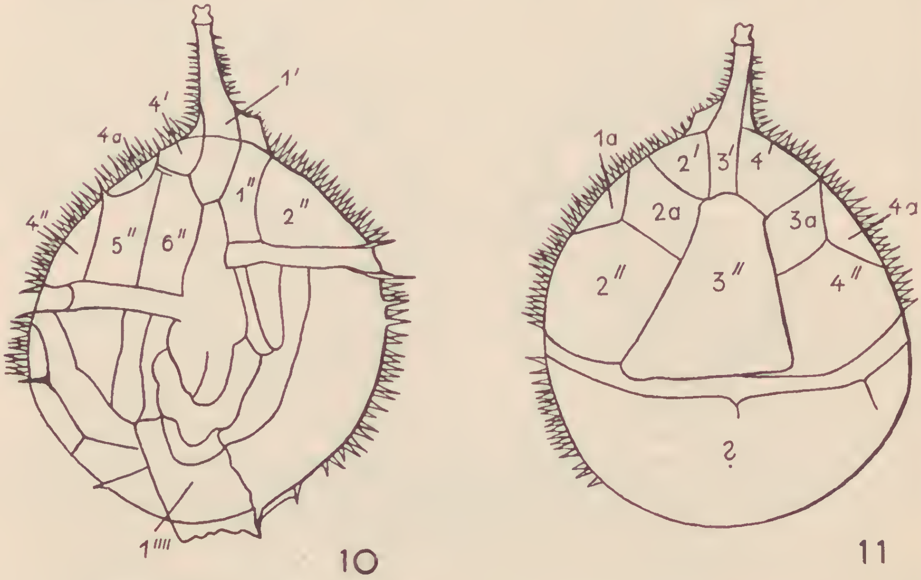
Comments. The long narrow shape, smooth surface and absence of ornamentation distinguish *G. apionis* from all other known fossil species of *Gonyaulax*. A form very similar to it has been recovered by one of us (A.E.) from the Aptian of Northern Germany.

Gonyaulax diaphanis sp. nov.

(Holotype—Pl. III, figs. 13, 14. Figs. 10, 11)

Age and occurrence. Lower Cretaceous (Aptian or older). South Perth Formation, W.A., Attadale Bore at 999 ft.

Description. Shell ovoid, epitheca smaller than hypotheca with a straight, stiff horn. Girdle helicoid. Both the plates and girdle are bordered by spiny ledges, those



FIGS. 10-11.—*Gonyaulax diaphanis* sp. nov. ventral and dorsal surfaces. South Perth Formation, W.A., × 525.

around the antapical plate appear to lie obliquely to it. The longitudinal furrow narrows towards the epitheca, and in it the pore for the exit of the flagellum can be seen. The arrangement of the plates is shown in Fig. 10, those on the dorsal surface of the hypotheca are not clear enough for representation.

Dimensions. Holotype—128 μ x 100 μ overall.

Gonyaulax spp.

(Pl. III, figs. 8, 9)

The specimens from Seismic shot hole L.8 at 240 ft. near Gingin, W.A. (Pl. III, fig. 8), and from the Gearle Siltstone (lower part), Rough Range at 2360-75 ft., while providing evidence of their connection with *Gonyaulax,* are not sufficiently well preserved for specific characterization.

Family Hystrichodinidae

Genus **Hystrichodinium** Deflandre

Hystrichodinium amphiacanthum sp. nov.

(Pl. V, fig. 9; holotype)

Age and occurrence. Upper Jurassic or Lower Cretaceous (Neocomian): Omati, Papua, I.E.C.'s Well No. 1, samples 19, 20, 24.

Description. This is a delicate form and most of the specimens are imperfectly preserved. The shell of the type is almost spherical and is provided with a narrow, faintly marked girdle and nine processes, four at one pole and five at the other. The processes are long and pointed, and widen towards the membrane. The membrane of the shell is delicate and no trace of surface markings remains. The main features of this species, i.e., the median girdle and the polar position of the processes, have been confirmed by less perfect paratypes.

Dimensions. Type—173 μ overall; shell 52 μ x 71 μ; processes 43-62 μ long.

Comments. Only two species of *Hystrichodinium* have been described, the genotype *H. pulchrum* Defl. from Senonian and Cenomanian flints of France and Belgium respectively (Deflandre 1936, p. 36), and *H. oligacanthum* Deflandre and Cookson (1955) from the Albian deposit at Onepah Station in New South Wales. In both of these species the processes arise from the general surface of the shell, including the rim of the girdle. In *H. amphiacanthum* they are clearly confined to the polar areas.

Genus **Palaeohystrichophora** Deflandre

Palaeohystrichophora infusorioides Defl.

(Pl. X, fig. 10)

Palaeohystrichophora infusorioides Defl. 1936. *Ann. Paléont* 25; 38, Pl. IX, fig. 8.

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 8 at 1530-48 ft. and Well No. 5 at 1570 ft.

Description. The Australian examples of this species agree closely with the French types from Villers-sur-Mer (Cenomanian Flints) and the Paris Basin (? Senonian Flints) described by Deflandre. As far as can be judged from the magnification of Deflandre's figures (no measurements are recorded in the text), the Australian specimens are somewhat larger than their French counterparts having an overall range in length of 47-71 μ and breadth of 33-57 μ. The example

shown in Pl. X, fig. 10 is 57 μ x 43 μ. *P. infusorioides* occurs abundantly in the upper portion of the Gearle Siltstone.

Palaeohystrichophora isodiametrica sp. nov.

(Pl. XII, figs. 11, 12; holotype, fig. 12)

Age and occurrence. Upper Cretaceous (Campanian to Lower Maestrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1380-88 ft.

Description. The shell is approximately isodiametric and divided somewhat unequally by a straight girdle with low borders; both the epitheca and hypotheca are broadly dome-shaped to flat. The outer membrane, which is thin and transparent and lies close to the internal capsule, especially at the apex and antapex, is covered with numerous long wavy appendages.

The example shown in Pl. XII, fig. 11 has a large trapezoid-shaped pylome which stretches from just below the apex to the girdle.

Dimensions. Type—75 μ x 66 μ; girdle 6 μ; appendages *c*. 24 μ. Paratype (Pl. XII, fig. 11) 70 μ x 71 μ; girdle 5 μ; pylome 28 μ x 20 μ.

Comments. In the type of ornamentation, *Palaeohystrichophora isodiametrica* resembles *P. infusorioides* Defl., but differs from this species in being approximately as long as broad and in having broadly rounded apices and somewhat longer appendages. In *P. infusorioides* as preserved in the Gearle Siltstone, W.A. (Pl. X, fig. 10), the shell is fusiform and the appendages shorter and stiffer.

Palaeohystrichophora multispina Defl. and Cookson

(Pl. X, fig. 13)

Palaeohystrichophora multispina Defl. and Cookson, 1954. *Aus. J. Mar. Freshw. Res.* 6; 257, Pl. I, fig. 5.

Age and occurrence. ? Upper Cretaceous (Senonian): Molecap Greensand, Gingin, W.A. Lower Cretaceous (Albian): Cootabarlow Bore 2 at 581 ft.; Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7 at 2360-75 ft.; Well No. 1 at 2750 ft.

Description. During the present investigation a relatively large number of individuals which conform more or less exactly to the original description of *Palaeohystrichophora multispina* have been found. These have provided details that were not evident in the single flattened and broken specimen on which the species was based. The specimen shown in Pl. X, fig. 13 is representative of the new examples.

Extended diagnosis. The theca is broadly fusiform and has straight to convex sides; the "epitheca" is terminated by a shortly bifid process and the "hypotheca" by a sharply pointed spine. The transverse girdle is approximately equatorial but is not helicoid as was suggested as probable in the original description. The theca is covered with short, fine spines which are sometimes so small as to give the surface a granular appearance.

Dimensions. Type—56 μ x 38 μ. Range in new material—62-100 μ x 43-71 μ.

Palaeohystrichophora pellifera sp. nov.

(Pl. X, fig. 11; holotype)

Palaeohystrichophora cf. *spinosissima* Defl. and Cookson, 1955. 6; 258, Pl. IV, fig. 10.
non *Palaeohystrichophora spinosissima* (Defl.) in Deflandre and Cookson, 1955. *Aust. J. Mar. Freshw. Res.* 6; 257.

Age and occurrence. Lower Eocene: Princetown Member of Dilwyn Clay, Vic. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough

Range Well No. 1 at 2000 ft.; Styx River Series, Queensland, Queensland Geol. Surv. Bore 21 at 325 and 327 ft.

Description. The theca is broadly fusiform and divided unequally by the transverse girdle; the "epitheca" is terminated by a shortly bifid process, the "hypotheca" by a short pointed process. The surface is densely covered with spines *c.* 1-2·5 μ long.

Dimensions. Type—85 μ x 59 μ; the "Tertiary" specimen 122 μ x 56 μ.

Comments. From the present investigation it would appear that the genus *Palaeohystrichophora* is restricted to the Cretaceous period. It seems likely, therefore, that the example from the Princetown member of the Dilwyn Clay is a remanié fossil.

Palaeohystrichophora dispersa sp. nov.

(Pl. X, figs. 12, 14; holotype, fig. 14)

Age and occurrence. Probably Lower Cretaceous (Albian); near Gingin, W.A., Seismic shot hole B.2 at 230 ft.; King Edward Street Bore between 265 and 295 ft.

Description. Theca broadly fusiform, unequally divided by the transverse furrow, the larger "epitheca" being terminated by a short bifid process, the hypotheca by a sharply pointed process. The membrane of the theca is ornamented with rather widely dispersed small spine-like processes with truncate apices.

Dimensions. Type—80 μ x 53 μ. Range—64-90 μ x 38-62 μ.

Comments. P. dispersa can be distinguished from *P. pellifera* by the coarser nature of the spines, their truncate apices and wider dispersal.

The three species of *Palaeohystrichophora* just described, namely *P. multispina, P. pellifera* and *P. dispersa,* differ morphologically in several respects from *P. infusorioides* and *P. isodiametrica* and ultimately may prove generically distinct.

Family Incerta

Genus **Dingodinium** gen. nov.

Description. Theca consisting of a smooth, thin, transparent membrane without plates and a spherical to elongate-oval eccentrically placed capsule either covered with numerous small spines or smooth. A helicoid transverse furrow bounded on either side by a more or less distinct fold is always present on the outer membrane. Genotype—*Dingodinium jurassicum* sp. nov.

The name is derived from the Dingo Siltstone of the Cape Range, W.A., Jurassic succession in which the genotype is of frequent occurrence.

Dingodinium jurassicum sp. nov.

(Pl. I, figs. 10, 11; holotype, fig. 10)

Age and occurrence. Upper Jurassic: Dingo Siltstone (Upper), W.A., Wapet's Cape Range Well No. 1 at 3825-40 ft., and Well No. 2 at 3970-91 ft. and 4509-27 ft.; Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.; Omati, Papua, I.E.C.'s Well No. 1, sample 42 (Fig. 2).

Description. Shell usually longer than broad with a shallow girdle. The capsule, which tends to be flattened on the side in contact with the outer membrane, is covered with numerous small irregularly disposed spines.

Dimensions. Type—85 μ x 66 μ; capsule 62 μ x 47 μ. Overall range—76-100 μ x 66-85 μ; capsule 54-71 μ x 47-66 μ.

Dingodinium cerviculum sp. nov.

(Pl. I, figs. 12, 14; holotype, fig. 14)

Age and occurrence. Lower Cretaceous (Aptian): Muderong Shale, W.A., Wapet's Rough Range Well No. 8 at 3863-83 ft.: Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 4 at 3532-50 ft.; Wapet's Rough Range No. 4 at 3350 ft.; Omati, I.E.C.'s Well No. 1, samples 5, 9 (Fig. 2); Roma Series, North Queensland, Well on Batavia Downs Station between 45-49 ft.; Cootabarlow, S.A., Bore No. 2 at 1354 ft. Lower Cretaceous (? Aptian): South Perth Formation, W.A., Attadale Bore at 809 ft. Lower Cretaceous (Upper Neocomian or Lower Aptian): "Grierson Member", Birdrong Formation, W.A., Wapet's Well No. 3 at 1390-1400 ft. and Meadow Station Artesian Bore No. 9.

Description. Theca longer than broad, its outer membrane narrowing towards a relatively long terminal neck the end of which, in well preserved specimens, appears to be closed. The girdle is clearly defined and helicoid. The capsule is elongated longitudinally and usually flattened on the side in contact with the outer membrane; it is covered with small spine-like outgrowths which may be arranged in regular longitudinal rows or scattered irregularly over the surface.

Dimensions. Type—109 μ x 66 μ overall; capsule 65 μ x 52 μ. Range—81-109 μ x 33-66 μ; capsule 47-65 μ x 28-52 μ.. Range—81-109 μ x 33-66 μ overall; capsule 47-65 μ x 28-52 μ.

Comments. The real affinity of the genus *Dingodinium* cannot be fixed with certainty. The presence of a girdle indicates relationship with the Dinoflagellata, the occurrence of a capsule within a thin enclosing membrane suggesting a position near the family Deflandreidae.

Palaeoperidinium cf. ventriosum (O. Wetzel)

(Pl. III, fig. 10)

Peridinium ventriosum O. Wetzel, 1933. *Palaeontographica* 77; 161, 162, Fig. 1. 78, Pl. II, figs. 4, 6.

Palaeoperidinium ventriosum G. Deflandre, 1935. *Bull. Biologique*, 69; 228, Pl. V, fig. 5 and Pl. VI, figs. 9, 10.

Age and occurrence. Lower Cretaceous (Aptian): Muderong Shale, W.A., Wapet's Rough Range Well No. 8 at 3863-83 ft.

Description. Shell almost spherical, epitheca slightly conical terminated by a short cylindrical horn with a small conical apex. The girdle is approximately equatorial and has low borders. The longitudinal furrow is indistinct. The sutures of the plates are low and generally masked by the rather coarse granulation of the general surface.

Dimensions. 81 μ x 71 μ.

Comments. The reference of this specimen to the form genus *Palaeoperidinium* is only provisional until such time as more information about it is obtained. *Palaeoperidinium ventriosum* has been recorded from flints of the Baltic region (? Senonian) and of the Paris Basin (? Senonian) (Deflandre 1936, p. 28).

Genus Muderongia gen. nov.

Description. Test flattened. bilaterally symmetrical, composed of a thin outer membrane and an internal body or capsule. The outer membranes prolonged into four equidistant horns and crossed by a narrow shallow girdle. A longitudinal furrow is not developed. Genotype—*Muderongia mcwhaei* sp. nov.

Comments. The external form of *Muderongia* is somewhat similar to that of *Ceratocystidiopsis* Deflandre, *Pseudoceratium* Gocht and *Odontochitina* Defl. However, it is distinct from all three in having a transverse girdle and from *Pseudoceratium* and *Odontochitina* in having an internal capsule.

The taxonomic position of *Muderongia* is uncertain, but its shape and the development of a girdle suggest a connection with the dinoflagellates.

Muderongia mcwhaei sp. nov.

(Pl. VI, figs. 1-5; holotype, fig. 2)

Age and occurrence. Lower Cretaceous (Aptian): Muderong Shale, W.A., Wapet's Rough Range Well No. 8 at 3863-83 ft.; Cootabarlow, S.A., Bore No. 2 at 1165 and 1354 ft. Lower Cretaceous (? Aptian): South Perth Formation, W.A., Attadale Artesian Bore at 809 ft.

Description. The test is roughly rhomboidal in outline and prolonged into two straight median horns (apical and antapical respectively) and two curved and downwardly directed lateral horns of varying lengths; near the points of origin of the horns, smaller more irregular outgrowths may develop (Pl. VI, fig. 3).

The capsule has a smooth, moderately thick wall and entirely fills the central cavity of the test, sometimes even extending into the proximal ends of the horns. The girdle is represented by two fine, closely-opposed, straight lines which completely cross the equator of the test (Pl. VI, fig. 4).

Frequently the extreme distal region of the test becomes detached by a split which develops beneath the base of the apical horn.

The species is named after Dr. Ross McWhae, Geologist, West Australian Petroleum Pty. Ltd.

Dimensions. Type—161 μ x 74 μ overall; apical horn 47 μ long; capsule 62 μ x 57 μ. Other examples—(i) 166 μ x 57 μ overall; apical horn 52 μ long; (ii) 142 μ x 54 μ overall, apical horn 23 μ long.

Genus **Broomea** gen. nov.

Description. Test elongate with a longer apical horn and two shorter antapical horns. A shallow "girdle" situated below the middle of the body may be present. A pylome is developed in the apical region. Genotype—*Broomea ramosa* sp. nov.

Broomea ramosa sp. nov.

(Pl. VI, figs. 6-8; holotype, fig. 7)

Age and occurrence. Middle Jurassic: Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1 at 6365-83 ft. Upper Jurassic: Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.; Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2 at 3970-91 ft.; Omati, Papua, I.E.C.'s Well 1, samples 19, 27 (Fig. 2).

Description. Body elongate-oval with straight to convex sides narrowing slightly towards the apical horn, broader basally at the place of origin of the antapical horns and divided into two unequal regions—a longer apical region and shorter antapical region—by a shallow "girdle" indicated on the surface by two rather faint parallel straight lines; a somewhat hoof-shaped pylome is developed in the apical region of the same surface.

The apical horn tapers gradually to a short, straight solid terminal point; the two antapical horns which are of unequal size become more or less completely divided longitudinally into a varying number of somewhat ragged, pointed filaments.

The membrane is granular, more coarsely so in the antapical region.

Dimensions. Holotype—214 μ x 38 μ overall; apical horn *c.* 76 μ, larger antapical horn *c.* 38 μ. Range—176-218 μ x 24-38 μ overall; apical horn 76-90 μ.

Broomea simplex sp. nov.

(Pl. VI, fig. 9; holotype)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C.'s Well 1, sample 24 (Fig. 2).

Description. Body broader proximally narrowing towards a long tapering apical horn, antapical horns 2, entire, widely divergent with broad bases and rounded apices. A "girdle" is apparently absent, a pylome is developed in the apical region; the membrane is finely granular.

Dimensions. Type—285 μ x 33 μ overall; apical horn *c.* 118 μ, antapical horns 76 μ x 52 μ. A paratype—314 μ x 33 μ overall; apical horn *c.* 118 μ, antapical horns *c.* 76 μ and 62 μ.

Comments. Our attention was drawn by Professor T. Braarud to the strong morphological agreement, even to the detailed form of the apical horn, that exists between *Broomea ramosa* and *Podolampas spinifer,* Okamura (in Schiller 1937). However, since the fossil specimens referred to as *Broomea ramosa* and *B. simplex* have shown no trace either of the wings accompanying the antapical spines of *P. spinifer* and other species of *Podolampas* or of tabulation, and moreover have a distinct pylome, a feature unknown in *Podolampas,* it seems preferable for the present at least to place the fossils species in a separate genus.

Order HYSTRICHOSPHAERIDEA

Family HYSTRICHOSPHAERIDAE

Genus **Hystrichosphaeridium** Deflandre

Hystrichosphaeridium complex (White)

(Pl. XII, fig. 10)

Xanthidium tubiferum complex White, 1842. *Micr. J.* 2; Pl. IV (3), fig. 11. 1844. *Trans. Micr. Soc.* 1; 83, Pl. VIII, fig. 10.

Hystrichosphaeridium elegantulum Lejeune-Carpentier, 1940. *Ann. Soc. Géol. Belg.* 63; B 222, figs. 11-12.

Hystrichosphaeridium complex (White) Deflandre, 1946. *C.R. Soc. Géol. Fr.,* 111.

H. cf. *tubiferum* sec. Cookson, 1953. Pl. II, fig. 24.

Age and occurrence. Upper Cretaceous: Nelson Bore, Vic., at 5782 and 6192 ft. Upper Cretaceous (? Senonian): Molecap Greensand, W.A. Lower Cretaceous (Albian): Onepah Well, N.S.W.; Styx River Series, Queensland Geological Survey Bore 21 at 327 ft.; Cootabarlow, S.A., Bore No. 2 at 581 ft. and Gearle Siltstone, W.A., Wapet's Rough Range Well No. 1 at 2000 and 2750 ft. Lower Cretaceous (Albian-Aptian): Omati, Papua, I.E.C. Well 1, sample 5 (Fig. 2). Lower Cretaceous (Aptian): Muderong Shale, W.A., Wapet's Rough Range Well No. 8 at 3863-83 ft.; Roma Series, North Queensland, Batavia Downs Station Well between 45 and 49 ft. Lower Cretaceous (Upper Neocomian or Lower Aptian): Grierson Member, Birdrong Formation, W.A., Wapet's Well No. 3 at 1390-1400 ft.

Comments. Hystrichosphaeridium complex was originally recorded from European Upper Cretaceous deposits. The above record has extended its range to cover the greater part of the Cretaceous period. One of us (A.E.) has identified *H. complex* in a north German Aptian deposit.

Hystrichosphaeridium recurvatum (White)

Xanthidium recurvatum White (1842) 1844. *Trans. Micr. Soc.* 1; Pl. VIII, fig. 11.
Hystrichosphaeridium recurvatum (White) Lejeune-Carpentier, 1940. *Ann. Soc. Géol. Belg.* 63; B 221, fig. 6.

Age and occurrence. Upper Cretaceous (Campanian to Lower Mastrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1380-88 ft. Upper Cretaceous (? Senonian): Molecap Greensand, Gingin, W.A. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7 at 2360-75 ft.; Wapet's Rough Range Well No. 1 at 2750 ft.; Cootabarlow, S.A., Bore No. 2 at 581 ft.; Onepah Well, N.S.W.; Styx River Series, Queensland Geological Survey Bore No. 21 at 327 ft. Lower Cretaceous (Aptian): Roma Series, North Queensland, Well on Batavia Downs Station between 45-49 ft.

Comments. The same two forms of *H. recurvatum* that were observed by Deflandre and Cookson (1955, p. 269), are present in the sediments recorded above. The one with fewer and larger appendages agrees more closely with the type of the species. The other form is readily distinguished by the smaller shell and greater number of finer appendages.

Hystrichosphaeridium anthophorum sp. nov.

(Pl. XI, figs. 12, 13; holotype, fig. 12. Figs. 16-18)

Age and occurrence. Upper Jurassic: Broome, W.A., Artesian Bore No. 3 at 1390-1400 ft. Lower Cretaceous (Aptian-Albian): Omati, Papua, I.E.C. Well 1, samples 5, 9 (Fig. 2).

16 17 18

FIGS. 16-18.—*Hystrichosphaeridium anthophorum* sp. nov. undividual appendages. Omati, Papua, × 625.

Description. Shell spheroidal and provided with about 10-15 stalked tubular appendages. The stalks of the appendages which are short and sometimes broad, and frequently show the longitudinal fibrils of which they are composed, gradually widen distally, frequently close to the shell, into deep broad terminal expansions with completely and irregularly reticulate walls and continuous smooth or finely serrated outer edges.

Dimensions. Holotype—Shell 70 μ, overall 210 μ; appendages *c.* 50 μ.

Comments. Hystrichosphaeridium anthophorum is morphologically close to *H. pulcherrimum* Deflandre and Cookson and *H. dictyoplocus* Klumpp. It differs from *H. pulcherrimum* in the more extensive reticulation of the appendages and the entire edge of the terminal expansion, and from *H. dictyoplocus* in the shorter

and somewhat broader appendages and the wider mesh and continuous margin of the terminal expansions.

Hystrichosphaeridium dictyophorum sp. nov.

(Pl. XI, fig. 14; holotype)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C. Well 1, sample 27 (Table 1).

Description. Shell spheroidal, provided with 10-15 appendages which have rather short, apparently solid stems, and abruptly delimited, widely expanded and open meshed terminal expansions with a smooth, continuous edge.

Dimensions. Holotype—diameter shell 71 μ, overall diameter 140 μ; appendages 42-47 μ.

Hystrichosphaeridium siphoniphorum sp. nov.

(Pl. XI, figs. 8-10; holotype, fig. 8)

Age and occurrence. ? Upper Cretaceous (Cenomanian): Subiaco, W.A., Water Bore at 358 ft. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Rough Range Well No. 7 at 2360-75 ft. and Rough Range Well No. 1 at 2000 ft. Probably Lower Cretaceous (Albian): Gingin, W.A., Seismic shot hole L.8 at 240 ft. and B.2 at 230 ft., and Osborne Park, W.A., King Edward Street Bore at 265-95 ft.

Description. Shell spherical or slightly oval, with a rather thick, granular wall, and approximately 13 hollow conical to tube-like processes of somewhat unequal width that are open to the exterior and have a slightly recurved margin. A large pylome has been present in some examples.

Dimensions. Type—overall diameter 76 μ diameter of shell 43 μ, length of processes *c.* 19-24 μ. Paratype (Pl. XI, fig. 9)—overall diameter 69 μ, shell 33 μ length of processes *c.* 14 μ; "lid" of pylome 21 μ.

Comments. This species seems to have some affinity with *H. salpingophorum* Defl., *H. truncigerum* Defl. from the French Upper Cretaceous (Senonian) and *H. striatoconus* Deflandre and Cookson from the Molecap Greensand, W.A., but is clearly distinct from all three species.

Hystrichosphaeridium cf. **hirsutum** (Ehr.)

(Pl. XI, fig. 13)

Xanthidium hirsutum Ehrenberg 1836. *Abh. Kgl. Akad. Wiss., Berlin, aus. J.* 1836.

Age and occurrence. Probably Lower Cretaceous (Albian): Gingin, W.A., Seismic shot hole B.2 at 230 ft. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7 at 2360-75 ft. Lower Cretaceous (Albian-Aptian): Omati, Papua, I.E.C. Well 1, sample 5 (Fig. 2).

Comments. A few specimens have been observed in preparations of the Gearle Siltstone and Omati samples that can be related to the group of *Hystrichosphaeridiums* comprising *Hystrichosphaeridium hirsutum* (Ehr.), *H.* cf. *spinosum* (White), *H.* cf. *spinosum* (White) var. *deflandrei* Lejeune-Carpentier, *H. pseudhystrichodinium* Deflandre and *H. crassipes* (Reade) as reviewed by Lejeune-Carpentier (1941).

The spines of the Australian type agree most closely with those of *H. hirsutum*, *H.* cf. *spinosum* and *H.* cf. *spinosum* var. *deflandrei* but the fibrils that run back

from them on to the surface of the shell, give rise to the same type of surface marking as that present in all members of the "*hirsutum*" group.

Some of these species are not easily separated from one another, so that until more material is available, and comparison with the types and paratypes of the European species is possible, it seems better that the Australian form should not be directly referred to anyone of them.

The European species have only been recorded from the Upper Cretaceous, mainly the Senonian.

Hystrichosphaeridium parvispinum sp. nov.

(Pl. VIII, figs. 10-12)

Holotype: *Hystrichosphaeridium xanthiopyxides* O. Wetzel var. *parvispinum* Deflandre 1937. *Ann. Paléon.* 26; Pl. 13, fig. 5 (Deflandre collection AF31).

Age and occurrence. Lower Cretaceous (probably Aptian): Omati, Papua, I.E.C. Well 1, sample 5 (Fig. 2). Lower Cretaceous (Aptian): Roma Series, Queensland, Batavia Downs Station Well between 45-49 ft.

Description. Shell elongate-oval with a distinctly granular membrane and numerous short, sharply-pointed spines, the tips of which are sometimes recurved (Pl. VIII, fig. 11).

Dimensions. Holotype (estimated from drawing)—shell 40 μ x 20 μ. Australian paratype (Pl. VIII, fig. 10)—84 μ x 46 μ overall, shell 76 μ x 33 μ; a second complete specimen—85 μ x 43 μ overall, shell 73 μ x 32 μ.

Comments. The Australian examples of *H. parvispinum* are undoubtedly specifically distinct from the German Senonian species *H. xanthiopyxides* O. Wetzel. However, apart from their considerably greater size, they appear to be identical with the French specimen described by Deflandre under the name *H. xanthiopyxides* var. *parvispinum*. This is the more probable since both are of Aptian or near Aptian age.

Genus **Coronifera** gen. nov.

Description. Shell roughly oval in outline, with an often denticulate tubular horn at one pole and a stiff pointed process at the other; the surface provided with simple or bifurcate appendages. Genotype *Coronifera oceanica* sp. nov.

Coronifera oceanica sp. nov.

(Pl. XII, figs. 5, 6; holotype, fig. 6)

Age and occurrence. Lower Cretaceous (Albian): Wapet's Rough Range Well No. 7 between 2360-75 ft., Moora Bore between 86 and 170 ft.

Description. In the type specimen, the shell is approximately oval in outline and prolonged at one end into a straight, four-sided tubular horn with a denticulate edge, and at the other into a stiff pointed spine. The surface is granular and covered with rather long and flaccid, thin, simple or more usually bifurcate appendages.

In the specimen shown in Pl. XII, fig. 5, the larger tubular horn is considerably compressed and the pointed spine appears to be missing; in addition, the bases of some of the appendages on one side have fused, forming a denticulated ledge.

Dimensions. Type—90 μ x 81 μ overall; shell 57 μ x 48 μ; hollow horn 17 μ long. Specimen shown in Pl. XII, fig. 5—105 μ x 86 μ overall; shell (without horn) 76 μ x 36 μ; horn 14 μ long.

Comments. A specimen which agrees well with the type of *Coronifera oceanica* has been found by one of us (A.E.) in the Upper Aptian of northern Germany.

Genus **Cannosphaeropsis** O. Wetzel

Cannosphaeropsis utinensis O. Wetzel

Sub-species **filifera** nov. sub. sp.

(Pl. VII, fig. 4; holotype)

Age and occurrence. Upper Cretaceous (Campanian to Lower Maestrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1380-88 ft.

Description. Shell spherical, smooth with a number of processes of unequal lengths and width, which, by their branching and coalescence, give rise to a loose external network. Some of the main branches are flattened and relatively broad; short branches bearing 3 or 4 slender hairs are developed at or near some of the points of branching.

Dimensions. Holotype—overall diameter *c.* 185 μ, diameter of shell *c.* 104 μ.

Comments. Thanks to the co-operation of Dr. Otto Wetzel, it has been possible to compare our specimen with the holotype of *C. utinensis* O. Wetzel which it strongly resembles. The tertiary branchlets however are less frequent than in *C. utinensis* and are filiform and not stiff and spine-like as in that species. The flattening of the supporting processes which is not evident in the holotype of *C. utinensis,* has been shown by Deflandre (1937, Pl. XVI, fig. 12) to occur in a specimen from a Parisian Senonian flint.

Cannosphaeropsis fenestrata Deflandre and Cookson

(Pl. VII, figs. 1-3)

Cannosphaeropsis fenestrata Defl. and Cookson 1955. *Aust. J. Mar. Freshw. Res.*; 283, Pl. III, fig. 2.

Age and occurrence. ? Upper Cretaceous (Cenomanian): Subiaco Water Bore, Perth, W.A., at 358 ft. Upper Cretaceous (? Senonian): Molecap Greensand, Gingin, W.A. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7 at 2360-75 ft. Lower Cretaceous (Aptian to Lower Albian): Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 4 at 3532-50 ft.

Comments. Five specimens isolated from Western Australian Cretaceous deposits, although not in exact agreement with the type, are referred provisionally to *Cannosphaeropsis fenestrata* described from the Molecap Greensand, W.A. They have rather smaller shells and the threads composing the enveloping network are finer, less flattened and scarcely or not at all perforated. See Appendix 2.

Cannosphaeropsis aemula Defl.

(Pl. VII, fig. 5)

Hystrichosphaeridium aemulum Deflandre 1938. *C.R. Acad. Sci. Paris* 264; 653, Fig. 6.
Cannosphaeropsis aemula Deflandre 1947. *C.R. Acad. Sci. Paris* 224; 1576.

Age and occurrence. Upper Jurassic: Era River district, Papua, Australasian Petroleum Co.'s Wanna Well, sample 451. (The age of this sample was given by Deflandre and Cookson (1955, p. 283) as Lower Cretaceous. We have been informed by Mr. J. N. Montgomery, Geologist to Australasian Petroleum Co., that it is now believed to be Upper Jurassic.) Omati, Papua, I.E.C. samples 19, 20, 26, 31, 33, 35, 36 (Fig. 2); Dingo Siltstone, W.A., Wapet's Cape Range Well No. 2 at 3970-91 ft., 4509-21 ft. and 6030-60 ft., Wapet's Cape Range Well No. 1 at 3825-40 ft.; Broome Artesian Bore No. 3 at 1405-27 ft.

Comments. The specimens of *C. aemula* from the Australian and New Guinea Jurassic deposits, have varied considerably in the degree of development of the funnel-like processes and the profuseness of the connecting threads, but all have possessed the hollow perforated extremities characteristic of this species as described by Deflandre (1938).

According to the records of Deflandre (1938, p. 189), *C. aemula* ranges from the Dogger (East Prussia) to the Oxfordian (Villers-sur-Mer, France).

Cannosphaeropsis aemula sub. sp. **integra** sub. sp. nov.

(Pl. VII, figs. 6, 7; holotype, fig. 6)

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2 at 6032-60 ft. Middle Jurassic (Lower Callovian): Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1 at 6365-83 ft.

Description. Shell spheroidal with a number of hollow, funnel-like processes the walls of which are, for the most part, entire or only very slightly perforated. The "funnels" are connected by short delicate threads.

Dimensions. Overall diameter 95-128 μ, shell 48-62 μ, processes 24-38 μ long.

Comments. The sub-species *integra* is readily distinguishable from typical examples of *C. aemula* such as that shown on Pl. VII, fig. 5 by the rather shorter, broader and more entire processes. It seems to have been a delicate form, for usually the "funnels" and connecting strands are partially destroyed, while those of typical examples of *C. aemula* in the same preparation are intact.

C. aemula sub-species *integra* is the dominant microfossil in the Middle Dingo Siltstone of Cape Range No. 1 Well at 6360 ft., where it is very abundant. It is much less frequent in the Upper Dingo Siltstone of Cape Range Well No. 2 between 6032 and 6060 ft., and has not been observed at higher levels.

Cannosphaeropsis filamentosa sp. nov.

Pl. VIII, figs. 8, 9; holotype, fig. 9. Pl. VIII, figs. 1, 2)

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2 at 6032-60 ft.; Learmonth Formation, W.A., Wapet's Rough Range Well No. 1 at 4376-79 ft. Middle Jurassic (Lower Callovian): Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1 at 6365-83 ft.

Description. Shell approximately spherical, provided with a varying number of thin, solid processes which branch distally, sometimes in a fan-shaped manner, to form by their coalescence an open or sometimes dense enveloping network.

Dimensions. Holotype—overall diameter 124 μ, shell 48 μ.

Comments. C. filamentosa is distinct from *C. aemula* in that the processes supporting the enveloping network are more uniform in size and never possess the hollow extremities of that species. *C. filamentosa* is restricted to the deeper portions of the Cape Range Upper Jurassic sequence, where it occurs together with *C. aemula* and *C. aemula* sub. sp. *integra*, and the upper portion of the Middle Jurassic where it occurs with *C. aemula* sub. sp. *integra*.

In the sample from Rough Range Well No. 1 at 4376-79 ft., *C. filamentosa* alone has been found.

Specimens having the same characters as *C. filamentosa* have been discovered by Mr. Karl Klement of the University of Tübingen in the *Peltoceras transversarium* zone of the lowest part of the Upper Jurassic of Southern Germany (Swabia) (personal communication).

It would appear from the present work that *C. filamentosa* has a more limited range than *C. aemula*, and therefore could be of some stratigraphical value.

Cannosphaeropsis mirabilis sp. nov.

(Pl. VIII, figs. 3-5; holotype, fig. 3)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C. Well No. 1, samples 19, 20, 25, 26, 29 (Fig. 2).

Description. Shell elongate-oval, membrane thin, firm, smooth with 4-6 approximately longitudinal rows of evenly-spaced, solid processes which are connected with one another both proximally and distally by short threads to form a rather small-meshed superficial network. Short spine-like outgrowths are sometimes present on the connecting threads. In the holotype, a pylome appears to be present at one end of the shell.

Dimensions. Type—90 μ x 62 μ overall; shell, 62 μ x 35 μ. Range—90-109 μ x 57-71 μ overall; shell 62-85 μ x 28-52 μ.

Comments. This species, whilst never abundant, is not rare in the upper portion of the Omati Upper Jurassic (Fig. 2). Some of the samples in which it occurs, namely numbers 20, 25, 26 and 29, definitely belong to the Upper Jurassic, but the age of sample 19 is less certain and may be Neocomian. However, the general impression obtained from this study, is that *C. mirabilis* is essentially an Upper Jurassic type.

C. mirabilis is distinct from all known species of *Cannosphaeropsis* in the elongated form of the shell. However, since oval as well as spherical shells are now unquestioningly included in the genus *Hystrichosphaeridium* Defl., it has been considered preferable to enlarge our conception of the genus *Cannosphaeropsis* than to create a new genus for *Cannosphaeropsis-like* forms having shells that are longer than broad.

Genus **Cyclonephelium** Deflandre and Cookson

Cyclonephelium compactum Defl. and Cookson

(Pl. XII, figs. 7, 10)

Cyclonephelium compactum Defl. and Cookson 1955. *J. Mar. Freshw. Res.* 6; 285, Pl .II, figs. 11-13.

Age and occurrence. Upper Cretaceous (? Senonian): Molecap Greensand, Gingin, W.A. Probably Lower Cretaceous (Albian): Osborne Park, W.A., King Edward Street Bore at 265-95 ft.; Gingin, W.A., Seismic shot hole L.8 at 240 ft. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 1 at 2750 ft.; Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7 at 2360-75 ft.; Cootabarlow, S.A., Bore No. 2 at 581 ft.; Onepah Well, N.S.W.

Description. Cyclonephelium compactum occurs in most Australian Albian deposits, the example shown in Pl. XII, fig. 7 being typical of the species.

The specimen from the Lower Gearle Siltstone (Pl. XII, fig. 8) varies from the type in the high degree of fusion that has taken place between the processes that form the equatorial ornament and the formation of homogeneous membranes with occasional perforations. The fine fibrils which pass back from the membrane on to the shell, are clearly shown.

The opening in this specimen is sharply defined and appears to have been in the nature of a pylome formed by the complete detachment of the wall of the shell in this

area. The overall diameter of this specimen is 83 μ; the diameter of the shell 75 μ and the opening or pylome 48 μ.

Family Pterospermopsidae

Genus **Pterospermopsis** W. Wetzel

Three species of *Pterospermopsis* have already been described from Australian deposits—one, *P. microptera* Defl. and Cookson from the Lower Tertiary, and two from the Cretaceous, *P. australiensis* Defl. and Cookson from Albian and *P. ginginensis* Defl. and Cookson from ? Senonian deposits.

At the time of their description it was observed that the ratio of wing to body was different in the two Cretaceous species, but from the small number of examples available, the full significance of this distinction could not be estimated.

Further examples of *Pterospermopsis* have been met with during the present investigation, and the genus is particularly well represented in the sample of the "Grierson Member" of the Birdrong Formation, W.A., from the Meadow Bore No. 9. The specimens have varied considerably in size but the majority have greatly exceeded that of both *P. australiensis* and *P. ginginensis*.

Whilst fully realizing that size alone is an unsatisfactory basis for specific determination, the difference here has been so great that we are provisionally distinguishing two additional species—*P. eurypteris* with the same ratio of wing to body as *P. australiensis*, and *P. aureolata* with the same ratio as that of *P. ginginensis*.

Only a detailed statistical study, such as is not possible at present, can determine whether the four types are specifically distinct or only wide variants of two or even one species.

Pterospermopsis aureolata sp. nov.

(Pl. IX, figs. 10-12; holotype, fig. 11)

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), Wapet's Rough Range Well No. 8 at 1530-48 ft. Lower Cretaceous (Aptian): Cootabarlow, S.A., Bore 2 at 1354 ft.; Muderong Shale, W.A., Wapet's Rough Range Well No. 8 at 3863-83 ft.; Roma Series, North Queensland, Batavia Downs Station Bore between 45-49 ft. Lower Cretaceous (Upper Neocomian or Lower Aptian): Probably "Grierson Member", Birdrong Formation, W.A., Meadow Station Bore No. 9.

Description. Body thick-walled, smooth, circular in polar view, with a thin but firm equatorial wing of approximately the same width as the radius of the body.

Dimensions. Overall diameter 109-208 μ, body 62-109 μ; ratio of wing to body 1·4-2.

Pterospermopsis eurypteris sp. nov.

(Pl. VIII, figs. 9, 13; holotype, fig. 13)

Age and occurrence. Lower Cretaceous (Aptian): Cootabarlow, S.A., Bore No. 2 at 1354 ft.; Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 4 at 809 ft. Lower Cretaceous (? Aptian): South Perth Formation, W.A., Attadale Bore at 809 ft. Lower Cretaceous (Upper Neocomian or Lower Aptian): Probably "Grierson Member", Birdrong Formation, W.A., Meadow Station Bore No. 9.

Description. Body circular in polar view, smooth, thick-walled, with a rather thick equatorial wing which is approximately equal to the diameter of the body.

Dimensions. Overall diameter 95-123 μ, body 36-49 μ; ratio of body to wing 2·5-2·7.

Genus **Cymatiosphaera** O. Wetzel

Cymatiosphaera pterota sp. nov.

(Pl. XI, fig. 7; holotype)

Age and occurrence. Upper Cretaceous (Campanian to Lower Maestrichtian): Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1384-86 ft. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone, W.A., Wapet's Rough Range Well No. 5 at 1570 ft. Probably Lower Cretaceous (Albian): Gingin, W.A., Seismic shot hole B.2 at 230 ft.

Description. Shell spherical, smooth, its surface divided into large fields by thin, smooth, relatively high membranes perpendicular to the surface. The margins of the membranes are frequently concave and sometimes minutely serrated.

Dimensions. Type—Overall diameter 66 μ, shell 43 μ; overall range 52-85 μ. Ratio of overall diameter to shell 1·4-1·5.

Comments. C. pterota differs from *C. wetzeli* Defl., a German Upper Cretaceous species, in the regular form of the fields and the distinctly higher membranes.

Cymatiosphaera stigmata sp. nov.

(Pl. IX, fig. 14; holotype)

Age and occurrence. Lower Cretaceous (Upper Neocomian or Lower Aptian): Probably "Grierson Member", Birdrong Formation, W.A., Meadow Station Bore No. 9.

Description. Shell spherical, thick-walled, the surface divided by low ledges into numerous polygonal fields (20-40), each of which has a small central thickening of circular outline.

Dimensions. Diameter of type 60 μ; of a paratype 43 μ.

Comments. Cymatiosphaera stigmata agrees with *C. punctifera* Defl. and Cookson from a Victorian Lower Tertiary deposit in having a small thickening in the centre of each field. However, it differs from that species in its larger diameter, in the greater number of fields and the lower ledges.

Cymatiosphaera punctifera	*Cymatiosphaera stigmata*
Diameter of type 23 μ	Diameter of type 60 μ
13 fields	about 40 fields
relatively high ledges	low ledges
Lower Tertiary	Lower Cretaceous

After a careful examination of the type of *C. punctifera*, the conclusion has been reached that there are at most 13 fields and not "17 or 18" as given by Deflandre and Cookson (1955, p. 289).

Genus **Membranilarnax** O. Wetzel

Membranilarnax leptoderma sp. nov.

(Pl. X, figs. 7, 9; holotype, fig. 9)

Age and occurrence. Lower Cretaceous (probably Albian): Omati, Papua, I.E.C. Well 1, sample 2.

Description. Shell rather thick-walled, spheroidal to slightly oval with a granular surface and, in the two specimens available, a large pylome at one pole. The outer thin membrane which envelops the shell, except over the pylome, is supported by very slender, widely separated processes, the ends of which are either bifurcate or slightly broadened.

Dimensions. Holotype—overall diameter 63-68 μ, diameter of shell 50 μ x 46 μ, pylome 25 μ; second specimen—overall diameter 60 μ x 53 μ, diameter of shell 40 μ x 37 μ, pylome 22 μ.

Comments. This species differs from other species of *Membranilarnax* in the rather wide space between the shell and the outer membrane, and the simple and distantly spaced supporting processes.

Membranilarnax sp.

(Pl. X, fig. 8)

Age and occurrence. Lower Cretaceous (probably Albian): Omati, Papua, I.E.C. Well 1, sample 2.

Description. Shell spheroidal with a rather thick granular wall. Enveloping membrane thin and undulating, supported by rather numerous fine processes which divide in such a way as to give a funnel-like appearance. A large pylome is present in the single specimen available.

Dimensions. Overall diameter 71 μ, diameter of shell 45 μ, pylome 24 μ.

Comments. Some uncertainty exists regarding the definition of the genus *Membranilarnax*, and Eisenack (1954) has placed forms comparable with the two forms just described in a separate genus *Samlandia* Eis. However, since, in a previous paper on Australian microplankton (Deflandre and Cookson 1955), species morphologically similar were referred to *Membranilarnax*, the present New Guinea Cretaceous species have been included in that genus pending early investigations of this problem by one of us (A.E.).

Family Leiofusidae

Genus **Leiofusa** Eisenack

Leiofusa jurassica sp. nov.

(Pl. X, figs. 3, 4; holotype, fig. 4)

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 1 at 3825-40 ft. and Well No. 2 at 3970-91 ft. and 4509-27 ft.

Description. Body spindle-shaped, prolonged into two horns of variable length; membrane transparent and smooth. Neither a transverse nor longitudinal furrow developed.

Dimensions. Type—72 μ x 14 μ overall; figured paratype—67 μ x 15 μ.

Comments. Leiofusa jurassica resembles *L. fusiformis* Eis. (1934) from Ordovician deposits of the Baltic region, but is smaller than this species.

It may also be compared with fusiform types described by O. Wetzel (1933) from Senonian flints under the name *Ceratium* cf. *fusus* (Ehr.) of which he has created several forms. However, from Wetzel's descriptions and figures it is not at all clear that, as the name would suggest, the tests had plates and furrows in which eventuality they would be quite distinct from *Leiofusa jurassica*.

The French Cretaceous form ? *Ceratium* cf. *fusus* (Ehr.) forma *incerta* Defl. is another fusiform type, the morphological characters of which are not sufficiently defined for comparison with *Leiofusa jurassica*.

Genus **Pyxidiella** gen. nov.

Description. Shell longer than broad, with straight or convex sides and rounded ends behind one of which a pylome is developed. Genotype—*Pyxidiella pandora* sp. nov.

Pyxidiella pandora sp. nov.

(Pl. VI, figs. 10, 11; holotype, fig. 10)

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2 between 3970-91 ft. and 4509-27 ft.; Era River District, Papua, Australasian Petroleum Co., Wana Well, sample 451.

Description. Shell cylindrical, with broadly rounded ends and a squarish pylome just behind one of them. Wall thin but firm, densely covered with small granules.

Dimensions. Type—48 μ x 32 μ. Range—48-57 μ x 24-43 μ.

Comments. Pyxidiella pandora is the most frequent individual type in the upper portion of the Dingo Siltstone where it occurs in very large numbers. Such an abundance would suggest that it represents a simple independent organism. The constant occurrence of a pylome, and its mode of development, suggest a relationship with the Hystrichosphaeridae.

Pyxidiella scrobiculata (Deflandre and Cookson)

Leiosphaera scrobiculata Deflandre and Cookson 1955. *Aust. J. Mar. Freshw. Res.* 6; 291, Pl. III, fig. 3.

Comments. The Upper Cretaceous and Tertiary shells described by Deflandre and Cookson (1955) appear to be related to *Pyxidiella*. For this reason they have been removed from *Leiosphaera* (Eisenack 1938), a genus which we think should be used, as originally intended, for spherical forms only.

Incertae Sedis

Nannoceratopsis pellucida Defl.

(Pl. X, figs. 5, 6. Fig. 19)

Nannoceratopsis pellucida Defl. 1938. *Trav. Stat. Zool. Wimereux* 13; 183, Pl. VIII, fig. 10.

Age and occurrence. Upper Jurassic: Dingo Siltstone (upper), W.A., Wapet's Cape Range Well No. 2 at 3970-91 ft. and 6032-60 ft.; Broome, W.A., Artesian Bore No. 3 at 1405-27 ft.; Omati, Papua, I.E.C. Well 1, samples 31, 35 (Fig. 2).

Comments. The Australian and New Guinea specimens although varying somewhat amongst themselves and from the French types are in sufficient agreement for reference to *Nannoceratopsis pellucida* from the Oxfordian of Villers-sur-Mer, France. A few of those from New Guinea have widely diverging antapical horns (Pl. X, fig. 6), however, it has not been possible to determine the constancy of this feature.

Previously *N. pellucida* has been known only from the one French locality. Its relatively frequent occurrence in deposits so far distant as north-west Western Australia and New Guinea is therefore of some geographical and possibly of stratigraphical interest.

Dimensions. Figured specimens—Pl. X, fig. 5, 125 μ x 57 μ; antapical horns 35 μ; Pl. X, fig. 6, 100 μ x 62 μ.

Genus **Ceratocystidiopsis** Deflandre

Ceratocystidiopsis ludbrooki sp. nov.

(Pl. V, figs. 7, 8; holotype, fig. 7)

Age and occurrence. Probably Lower Cretaceous (Albian): North of Gingin, W.A., shale from seismic shot hole B.1 at 230 ft.; Osborne Park, W.A., King Edward Street Bore at 265-95 ft. Lower Cretaceous (Albian): Cootabarlow, S.A.,

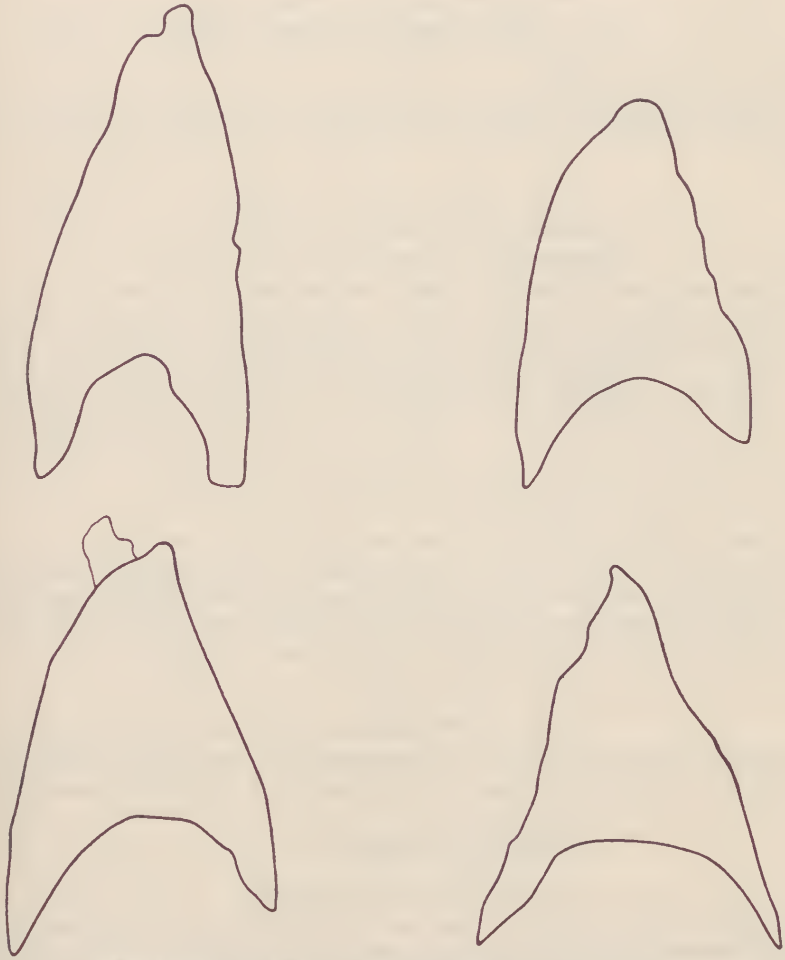


FIG. 19.—*Nannoceratiopsis pellucida* sp. nov. showing variation in shape of the test. Omati, Papua and Dingo Siltstone, W.A., × 500.

Bore 2 at 581 ft.; Gearle Siltstone (lower part), W.A., Rough Range Well No. 7 at 2360-75 ft.; Gearle Siltstone, Rough Range Well No. 1 at 2000 ft.

Description. Theca approximating in outline to an isosceles triangle with convex sides, a rather blunt obliquely directed apical horn and two divergent and somewhat unequal antapical horns with more pointed apices.

The internal capsule is sub-triangular with a flat base, convex sides and a blunt apex and is separated from the outer membrane by a space of variable width. The wall of the internal body is finely granular, that of the outer membrane smooth.

The apical region of the theca may become completely detached along an irregular line that extends obliquely across its upper portion (Pl. V, fig. 8).

The species is named after Dr. Nell Ludbrook, Palaeontologist, Dept. of Mines, South Australia.

Dimensions. Type—Overall length 190 μ, width of body 104 μ; apical horn *c.* 62 μ long; apical horn *c.* 33 μ; length of capsule *c.* 90 μ. Paratypes—Overall length 166 μ, width of body 109 μ; apical horn 57 μ; overall length 142 μ, width of body 85 μ; apical horn 38 μ.

Comments. Ceratocystidiopsis ludbrooki agrees in general features with *C. molesta* Defl. (1937) from the French Senonian, but differs from it both in size and shape.

Genus **Odontochitina** Deflandre

Odontochitina operculata (O. Wetzel)

Odontochitina operculata (O. Wetzel). *Aust. J. Mar. Freshw. Res.* 6; 291.

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 5 at 1570 ft. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 1 at 2000 ft. and 2750 ft.; Cootabarlow, S.A., Bore No. 2 at 581 ft.; Onepah Station, N.S.W.; Tooloombah Creek Area, Styx Coalfield, Queensland, Queensland Geological Survey Bore 21 at 327 ft. Probably Lower Cretaceous (Albian): Osborne Park (King Edward Street) Bore at 265-95 ft.; Omati, Papua, I.E.C. Well 1, sample 2 (Fig. 2).

Comments. This species was recorded from the Onepah well sample by Deflandre and Cookson in 1955. Since then examples have been isolated from the widely separated localities listed above. It would appear from these records that in the Australian area *Odontochitina operculata* is an Albian-Lower Turonian species. In Europe it has, so far, been recorded only from Senonian deposits.

Genus **Korojonia** gen. nov.

Description. Shell consisting of a smooth transparent broadly fusiform to oval membrane and an oval internal capsule. Genotype—*Korojonia dubiosa* sp. nov.

Korojonia dubiosa sp. nov.

(Pl. XII, fig. 13; holotype)

Age and occurrence. Upper Cretaceous (Campanian to Lower Maestrichtian); Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 between 1380-88 ft. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 5 at 1570 ft.

Description. Outer membrane broadly fusiform with blunt apices one of which sometimes carries a minute projection. The internal capsule is oval and thicker walled than the outer membrane from which it is separated by a rather wide space. Sometimes faint indications of an equatorial girdle can be seen at each side of the shell.

In most of the specimens, as in the type, the outer membrane of one side is partially folded over the shell.

Dimensions. Type—86 μ x 48 μ overall; cyst 48 μ x *c.* 33 μ. Range—66-95 μ x 38-48 μ overall.

Comments. Korojonia dubiosa seems to be related to the genus *Deflandrea* in some members of which, e.g. *D. bakeri* Defl. and Cookson, the two antapical horns typical of the genus as well as the girdle are considerably reduced or absent.

Genus **Pseudoceratium** Gocht

Pseudoceratium tetracanthum Gocht

Pseudoceratium tetracanthum Gocht, 1957. *Paläont Z.*, 31; 163-185.

Age and occurrence. Lower Cretaceous (Aptian): Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 4 at 3532-50 ft.; Roma Series, Queensland; Well on Batavia Downs Station between 45-49 ft. Lower Cretaceous (probably Aptian): Omati, Papua, I.E.C. Well No. 1, samples 5, 9 (Fig. 2).

Description. The Australian and New Guinea specimens agree in every respect with *Pseudoceratium tetracanthum* from the Upper Hauterivian (Neocomian) of Emsland in north-western Germany. Usually the specimens are found with the apical region detached but even then are readily recognizable by the slender form of the horns and the delicate body membrane. In these features, apart from the increased number of horns, *P. tetracanthum* is distinct from *Odontochitina operculata* (O. Wetzel) with which species it appears to have a close affinity.

Dimensions. Figured specimen—overall length 242 μ, length of body 90 μ, width of body 61 μ, apical horn 95 μ.

Pseudoceratium turneri sp. nov.

(Pl. V, figs. 2-6; holotype, fig. 3)

Age and occurrence. Lower Cretaceous (Albian): Gearle Siltstone, W.A., Wapet's Rough Range Well No. 1 at 2750 ft.; Onepah Well, N.S.W.; Cootabarlow S.A., Bore 2 at 581 ft.; Styx Series, Queensland, Queensland Geological Survey Bore 21 at 327 ft. Lower Cretaceous (probably Albian): Omati, Papua, I.E.C. Well No. 1, sample 4 (Fig. 2); Wapet's Moora Bore, W.A., between 86 and 170 ft. Lower Cretaceous (Aptian): Roma Series, Queensland; Well on Batavia Downs Station between 45-49 ft.

Description. Test either subtriangular with an oblique base and convex sides, prolonged into three horns of unequal length, a longer apical horn and two widely separated divergent antapical horns, or with a rounded base and one antapical horn. Frequently the apical region of the body becomes detached (Pl. V, fig. 6) near the base of the apical horn.

The ornament usually takes the form of narrow lamella-like membranes with irregular, frequently curved outlines of variable lengths formed by the distal coalescence of short bifurcate processes, the lamellae either remaining free or uniting to form a more or less complete superficial network.

Dimensions. Type—180 μ x 100 μ overall; apical horn 55 μ.

Comments. This very characteristic and variable form although referred to the genus *Pseudoceratium* on account of its shape and absence of an internal capsule is distinct from described European species in the type of ornamentation. It comes nearest in this respect to *P. pelliferum* Gocht but in this species the processes forming the ornament are always free from one another whereas in *P. turneri* they are usually united.

The species is named after Professor J. S. Turner of the University of Melbourne.

Genus **Fromea** gen. nov.

Description. Shell elongated, smooth with an equatorial "girdle" and a wide aperture at one end. Genotype—*Fromea amphora* sp. nov.

Fromea amphora sp. nov.

(Pl. V, figs. 10, 11; holotype, fig. 10)

Age and occurrence. ? Upper Cretaceous (Cenomanian): Subiaco, W.A., Artesian Bore at 358 ft. Probably Lower Cretaceous (Albian): Gingin, W.A., Seismic shot hole L.8 at 240 ft. and Gingin, W.A., Seismic shot hole B.1 at 230 ft; Moora Bore between 86 and 170 ft. Lower Cretaceous (Albian): Cootabarlow, S.A., Bore No. 2 at 581 ft.; Gearle Siltstone (lower part), W.A., Rough Range Well No. 7 at 2360-75 ft. and Well No. 1 at 2750 ft.; Onepah Station Well, N.S.W. Lower Cretaceous (Aptian): Roma Series, Cape York Peninsula, Well on Batavia Downs Station between 45 and 49 ft.

Description. Shell ellipsoidal, flattened, concave in the apertural region; wall *c.* 3 μ slightly thicker around the aperture. Equatorial "girdle" strongly indicated in the type, less so in other examples.

Dimensions. Type—81 μ x 62 μ; apertures 33 μ. Range—62-95 μ x 47-81 μ.

Comments. Deflandre (1937) has described under the name *Palaeostomocystis* small shells from the French Upper Cretaceous which have the general morphological features of *Fromea*. However, the latter is distinguished from *Palaeostomocystis* by the development of an equatorial "girdle".

Fromea amphora has a wide distribution in Australia mainly in deposits of Albian age. Its occurrence in the Roma Series of North Queensland (attributed to the Aptian), gives an Aptian-? Cenomanian time range, but although it is known from Albian and possibly younger deposits in Western Australia, it has not been observed in such Aptian deposits as the Muderong Shale or Windalia Radiolarite of that State.

Genus **Chlamydophorella** gen. nov.

Description. Shell enclosed in a delicate membrane that is supported by closely arranged slender, bifurcate spines of approximately equal length. Genotype—*Chlamydophorella nyei* sp. nov.

Chlamydophorella nyei sp. nov.

(Pl. XI, figs. 1-3; holotype, fig. 1)

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 5 at 1570 ft.; Wapet's Rough Range Well No. 8 at 1530-48 ft. ? Upper Cretaceous (Cenomanian): Subiaco, W.A., Water Bore at 358 ft. Probably Lower Cretaceous (Albian): Gingin, W.A., Seismic shot hole B.2 at 230 ft. and L.8 at 240 ft.; Moora Bore, W.A., between 86-170 ft. Lower Cretaceous (Albian): Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7 at 2360-75 ft.; Cootabarlow, S.A., Bore No. 2 at 581 ft.; Onepah Well, N.S.W. Lower Cretaceous (Aptian): Roma Series, Queensland, Batavia Downs well, Cape York Peninsula between 45 and 49 ft. Lower Cretaceous (probably Aptian): Omati, Papua, I.E.C. Well 1, sample 5 (Fig. 2). Lower Cretaceous (? Aptian): South Perth Formation, W.A., Attadale Bore at 809 ft.

Description. The shell is approximately spherical with a short peltate apical projection and is covered with numerous short, slender bifurcate processes which support a delicate membrane. The processes narrow from base to apex and are mostly inserted at right angles to the shell, but in the apical region lie parallel to the polar axis. The length of the spines differs slightly. They are longest on either

side of the equatorial region giving a slightly angular outline to the whole body and a median "girdle"-like appearance in optical section.

Dimensions. Type—48 μ x 43 μ overall; shell 38 μ x 35 μ; appendages 2·5-5 μ. Paratype (Pl. XI, fig. 2)—48 μ x 43 μ.

Comments. This type was previously recorded and figured by Deflandre and Cookson (1955, p. 273, Pl. VII, fig. 12) from the Onepah Well deposit, N.S.W., when the "angular outline recalling that of certain dinoflagellates" was noted. However, the specimens then available were considered insufficient for description and classification. Even now, when a relatively large number of specimens from a number of localities have been observed, only two have been found lying so as to give a proper idea of the shape of the organism.

The affinity of *Chlamydophorella nyei* is still obscure, its bilateral symmetry, rather angular outline and the suggestion of a "girdle", favour a connection with the dinoflagellates.

The fossil figured (Pl. XI, fig. 4) under the name *Chlamydophorella ?* sp., seems to be a species of that genus which has developed a large opening or pylome as the result of the breaking away of the apical region. It differs from *C. nyei* in the shorter, stouter and less numerous processes which bear the outer thin, transparent membrane. It seems probable that the shells of *C. nyei* opened in a similar manner.

The species is named after Mr. P. B. Nye, Director of the Bureau of Mineral Resources, Department of National Development, Commonwealth of Australia.

Genus **Wanaea** gen. nov.

Description. Shell hollow, widely cone-shaped, the edge almost but not completely surrounded by a lace-like edging, a length of about 24 μ being devoid of ornamentation (Pl. IX, fig. 7). The edging, which is of variable width, is composed of radially arranged processes that either anastomose or remain free. The existence of a closing membrane has been suggested by one specimen. Genotype—*Wanaea spectabilis* (Deflandre and Cookson).

Comments. In its general morphology *Wanaea* approaches most closely to the genus *Epicephalopyxis* of Deflandre. However, it differs from this genus in having a conical instead of a dome-shaped form, and in the presence of a lace or fringe-like edging. Furthermore, the forms included in *Wanaea* are obviously planktonic, whereas the genotype of *Epicephalopyxis, E. adherens* Defl., is an attached form.

Wanaea spectabilis (Defl. and Cookson)

(Pl. IX, fig. 1)

Epicephalopyxis spectabilis Deflandre and Cookson 1955. *Aust. J. Mar. Freshw. Res.* 6; 293, Pl. III, figs. 12-14.

Age and occurrence. Upper Jurassic: Era River District, Papua, Australasian Petroleum Company's Wana Wall sample 451; Omati, Papua, I.E.C. samples 36, 40, 42 (Fig. 2); Dingo Siltstone, W.A., Wapet's Cape Range Well No. 2 at 6032-60 ft.

Description. When this species was first described, the material available gave only a partial idea of the form of the shell as a whole. Now better preserved examples, isolated from the Omati deposits, have shown that it is widely cone-shaped with a small rounded apex (Pl. IX, fig. 1). As noted in the original description, the lacey edging is composed of radially arranged and sometimes bifurcate processes which are distally united.

Dimensions. Type—overall 110 μ x 84 μ, edging *c.* 8 μ. Paratype (Pl. VIII, fig. 1)—Depth 85 μ, maximum width 95 μ, width of edging *c.* 5 μ.

Wanaea digitata sp. nov.

(Pl. IX, figs. 2-5; holotype, fig. 2)

Age and occurrence. Upper Jurassic: Learmonth Formation, W.A., Wapet's Rough Range Well No. 1 at 4376-79 ft.; Broome, W.A., Artesian Bore No. 3 between 1405-27 ft.

Description. Shell broadly cone-shaped, narrowing towards a short, rounded apex; the edge is ornamented by a narrow fringe composed of finger-like or pointed processes which, although they may anastomose tangentially or coalesce proximally, remain free distally.

Dimensions. Holotype—depth 100 μ width 109 μ. Paratype (Pl. VIII, fig. 3)—width 110 μ; edging about 9·5 μ.

Comments. This species differs from *Wanaea spectabilis* in the structure of the ornament. In *W. spectabilis* the processes are united distally so that the edge of the "lace" is entire, whereas in *W. digitata,* although the bases of the processes may be united, the edge of the ornament is always frayed.

Wanaea clathrata sp. nov.

(Pl. IX, figs. 6-8; holotype, fig. 6)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C. samples 20, 26, 35 (Fig. 2); Dingo Siltstone (upper), W.A., Wapet's Cape Range Well No. 1 at 3825-40 ft. and Well No. 2 at 3970-91 ft. and 4509-45 ft.

Description. Shell narrowing to a rounded apex. Edging in the form of a relatively wide, rather irregularly constructed, small-meshed network with an entire edge, which narrows gradually towards the gap where it is entirely wanting (Pl. IX, fig. 7).

Dimensions. Holotype—depth 95 μ, maximum width 161 μ. Paratypes—147 μ wide, edging 24-33 μ.

Comments. The three species of *Wanaea* just considered appear to form an evolutionary sequence in which *W. digitata* is the simplest and *W. clathrata* the most highly developed form. This idea is supported, to some extent, by the stratigraphical occurrence of these species in the Omati and Cape Range Upper Jurassic deposits. In these, *W. spectabilis* appears to be restricted to the lower horizons (samples 36, 40, 42 (Fig. 2) in Omati Well No. 1 and to 6032-60 ft. in the Cape Range Well No. 2 sequence), whereas *W. clathrata* has been found only at higher levels (Omati samples 20, 26, 35 and Cape Range Well No. 2 at 3970-91 ft. and 4509-45 ft.).

Unfortunately the age of the Rough Range (No. 1 Well at 4376-79 ft.) and Broome (Oxfordian to Lower Kimeridgian according to Teichert (1940) and Tithonian according to Brunnschweiler (1945)) deposits, in which *W. digitata* occurs, is uncertain, but it is doubtful whether either is high in the Upper Jurassic.

Genus **Cyclodictyon** gen. nov.

Description. Microfossil consisting of a spherical or oval shell and a hollow-domed, equatorially-attached network. Genotype—*Cyclodictyon paradoxos* sp. nov.

Cyclodictyon paradoxos sp. nov.

(Pl. XII, figs. 1, 2; holotype, fig. 1)

Age and occurrence. Upper Cretaceous (Cenomanian to Lower Turonian): Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 5 at 1570 ft.; Rough Range Well No. 8 at 1530-48 ft.

Description. Shell small, smooth, thin-walled, compressed to an oval outline in all specimens. The net which is fine-meshed, folded and concavo-convex, is attached near the ends of the shell by broad, smooth, entire or occasionally divided, curved supporting strands which carry it well above the shell, so that its inner concave edges are separated from the shell by a considerable space.

The space separating the two sides of the net from one another has been small in all examples, but it seems highly probable that in life it was larger.

Dimensions. Type—overall 71 μ x 71 μ; shell 30 μ x 19 μ. Paratype—overall 76 μ x 71 μ; shell 33 μ x 24 μ.

Comments. In all, thirteen examples of this type have been found in samples of the Cenomanian to Lower Turonian portion of the Gearle Siltstone from two separate bores. The affinity of *Cyclodictyon paradoxos* is obscure, and it cannot be placed in any of the recognized families of fossil or living microplankton.

Genus **Dioxya** gen. nov.

Description. Shell fusiform, without plates and girdle, and with the two ends closed and of different shapes. Genotype—*Dioxya armata* sp. nov.

Dioxya armata sp. nov.

(Pl. XI, fig. 11. Holotype, Fig. 20)

Age and occurrence. Lower Cretaceous (probably Albian): Omati, Papua, I.E.C. Well 1, sample 2 (Fig. 2).

Description. Shell broadly fusiform with one end sharply pointed and smooth, the other broader, slightly truncate and with a few small terminal spines. The surface is covered with relatively thick, finger-like or occasionally pointed outgrowths, which in the type are irregularly arranged, and in other specimens are in parallel equatorial rows. The wall is rather thick, firm and transparent. In the type, the outline of a small squarish pylome is suggested near the more pointed end of the shell.

Dimensions. Type—55 μ x 40 μ overall. Paratype— 48 μ x 38 μ overall.

FIG. 20.—*Dioxya armata* Omati, Papua, × 1300.

Genus **Pareodinia** Deflandre

Pareodinia aphelia sp. nov.

(Pl. XII, figs. 3, 4, 9; holotype, fig. 4)

Age and occurrence. Lower Cretaceous (? Aptian): South Perth Formation, W.A., Attadale Bore at 999 ft. Upper Jurassic: Learmonth Formation, W.A., Wapet's Rough Range Well No. 1 at 4376-79 ft.; Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2 at 3970-91 ft. and 6032-60 ft. Middle Jurassic: Dingo Siltstone (middle part), W.A., Wapet's Cape Range Well No. 1 at 6365-83 ft.

Description. Shell with an acuminate or rounded apex and a short closed neck. Wall varying somewhat in thickness and firmness, granular to almost smooth.

Dimensions. Type—88 μ x 50 μ. Paratype (Pl. X, fig. 14)—105 μ x 52 μ. Range—66-114 μ x 33-62 μ.

Comments. It seems probable that this species, when better known, will be split into two distinct species (1) typified by the example taken as the present type (Pl. XII, fig. 4) in which the apex is rounded, the neck abruptly delimited and the wall firm and moderately thick, and (2) typified by the example illustrated in Pl. XII, fig. 9, in which the apex is acuminate, the wall thin, delicate and more strongly granular. However, other examples are less readily separable so that for the present at least, it seems better to include both forms in one broadly defined species.

Pareodinia aphelia is very similar to *P. ceratophora* Defl. from Upper Callovian deposits of the Baltic region and French Bajocian flints, and there is little doubt that the two species are closely related. *P. aphelia* is somewhat larger than *P. ceratophora.*

The specimen described by Deflandre (1938) from the French Oxfordian as *Palaeoperidinium spinosissimum* and later transferred by him to *Palaeohystrichophora* (Deflandre and Cookson 1955) is very similar to the example of *Pareodinia aphelia* shown in Pl. XII, fig. 9, only the occurrence of a girdle, said to be present in the French species, separating the two forms.

Genus **Omatia** gen. nov.

Description. Shell more or less fusiform, partially or completely covered by a delicate fin-like membrane. Genotype—*Omatia montgomeryi* sp. nov.

Omatia montgomeryi sp. nov.

(Pl. VIII, figs. 7-9; holotype, fig. 8)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C. Well 1, samples 25, 20, 19 (Fig. 2).

Description. Shell slightly pointed or with a short truncate neck at one end rounded at the other; surface granular, covered more or less completely by a narrow and delicate membrane which is supported by short, thin, simple or bifurcate processes which tend to be arranged in longitudinal rows. The membrane is widest and the processes most numerous at the two ends of the shell.

The species is named after Mr. J. N. Montgomery, geologist to Australasian Petroleum Co. Ltd.

Dimensions. Holotype—124 μ x 38 μ. Range 76-124 μ x 29-45 μ.

Omatia pisciformis sp. nov.

(Pl. VIII, fig. 6; holotype)

Age and occurrence. Upper Jurassic: Omati, Papua, I.E.C. Well 1, sample 20.

Description. Apex of shell broadly rounded, with a short, pointed, solid process which supports the outer membrane; antapex bluntly pointed. Shell membrane granular, thin outer membrane homogeneous, apparently restricted to the apical and antapical regions. In the single specimen available a large pylome is situated to one side of the mid-line and slightly below the apex; the "lid", which is oval in outline, is partially detached.

Dimensions. Holotype—142 μ long.

Comments. Omatia pisciformis differs from *O. montgomeryi* principally in the homogeneous texture of the thin outer membrane. No sign of the supporting processes evident in *O. montgomeryi* has been observed.

Microplankton Assemblages

The lists included in this section are intended as indications and not as complete representations of the microplankton assemblages present in the various deposits analysed. This applies particularly to the Gearle Siltstone and Korojon Calcarenite which are rich in Hystrichosphaerids the majority of which have been ignored during the present work. Species marked * have been recorded from the French Oxfordian. Species marked † have been recorded from the French and English Kimeridgian.

A. JURASSIC.

(i) Dingo Siltstone, Western Australia.

(a) Cape Range Well No. 1 at 6032-60 ft. and Well No. 2 at 6365-83 ft.

The microplankton at these levels is not rich in types and the preservation of those present is poor. The following forms have been recognized:

Dinoflagellata: *Gymnodinium crystallinum**; *Gonyaulax jurassica**†.

Hystrichosphaeridae: *Cannosphaeropsis aemula**, *C. aemula* sub. sp. *integra*, *C. filamentosa*.

Incertae Sedis: *Wanaea spectabilis* (6032-60 ft. only); *Broomea ramosa*; *Pareodinia aphelia*.

(b) Cape Range Well No. 2, 3970-91 ft.

This deposit contains a rich and varied assemblage and deserves fuller investigation. The types present are representative of the samples of the Upper Dingo Siltstone from Cape Range Well No. 1 at 3825-40 ft. and Well No. 2 at 4509-27 ft.

The Microplankton includes:

Dinoflagellata: *Gymnodinium crystallinum**, *G. luridum**; *Wetzeliella irregularis*; *Gonyaulax ambigua**, *G. jurassica**†, *G. scotti*; *Dingodinium jurassicum*.

Hystrichosphaeridae: *Cannosphaeropsis aemula**.

Leiofusidae: *Leiofusa jurassica*; *Pyxidiella pandora*.

Incertae Sedis: *Nannoceratopsis pellucida**; *Wanaea clathrata*; *Broomea ramosa*; *Pareodinia aphelia*.

(ii) Learmonth Formation, Western Australia. Rough Range Well No. 1 at 4376-79 ft.

The amount of organic material in this deposit was very small and some of the types present were too badly preserved for accurate identification.

The microplankton includes:

Dinoflagellata: *Gonyaulax jurassica**†.

Hystrichosphaeridae: *Cannosphaeropsis filamentosa.*

Incertae Sedis: *Wanaea digitata*; *Pareodinia aphelia.*

(iii) Broome, Western Australia. Bore No. 3 at 1405-27 ft.

This deposit of which only a small sample was available contains a well preserved microflora and microplankton assemblage. Several types have still to be classified.

The microplankton includes:

Dinoflagellata: *Gymnodinium crystallinum**, *G. luridum**, *G. parvimarginatum*; *Gonyaulax ambigua*†, *G. jurassica**†, *G. eisenacki* sub-species *oligodentata*; *Dingodinium jurassicum.*

Hystrichosphaeridae: *Hystrichosphaeridium anthophorum*; *Cannosphaeropsis aemula**.

Incertae Sedis: *Nannoceratopsis pellucida**; *Broomea ramosa*; *Wanaea digitata*; *Pareodinia aphelia.*

(iv) Omati, Papua. I.E.C. Well 1.

Although there is good palaeontological evidence that the upper limit of the Upper Jurassic in the Omati Well is at or near the level of sample 24 (Fig. 2), its exact position is not known with certainty. As far as the microplankton content is concerned, it has been found that some of the types present in or below sample 24 occur as high in the bore as sample 19, and for present purposes this level has been taken as the upper limit of the Jurassic, and not as Lower Cretaceous (Neocomian) as it may well be. Unfortunately no surely dated Neocomian deposits have been available for study, so that, as yet, we have no idea of the microplankton types that occurred in Australian waters during that period.

Most of the spores and microplankton in the Omati deposits are unfavourably preserved, and this applies especially to species of *Gonyaulax*, only two of which were sufficiently well defined for description. It is of interest to note the apparent absence of *Gonyaulax jurassica* from the Omati Jurassic sediments, a species that is well represented in Western Australian and European Jurassic deposits.

The microplankton includes:

(a) Samples 40-43 (Fig. 2).

Dinoflagellata: *Dingodinium jurassicum* (one example only).

Hystrichosphaeridae: *Cannosphaeropsis aemula**.

Incertae Sedis: *Wanaea spectabilis.*

(b) Samples 20-35 (Fig. 2).

Dinoflagellata: *Gymnodinium crystallinum** (Samples 24, 35); *Gonyaulax perforans* (Sample 31 only), *G. serrata* (Samples 20, 25).

Hystrichosphaeridae: *Cannosphaeropsis aemula**, *C. mirabilis* (Samples 20, 25, 26, 29).

Incertae Sedis: *Omatia montgomeryi* (Samples 20, 25), *O. pisciformis* (Sample 20); *Broomea ramosa* (Sample 27), *B. simplex* (Sample 24); *Wanaea clathrata* (Samples 20, 26, 35).

(c) Sample 19 (Fig. 2).

Dinoflagellata: *Gonyaulax serrata*; *Hystrichodinium amphiacanthum.*

Hystrichosphaeridae: *Cannosphaeropsis aemula**, *C. mirabilis.*

Incertae Sedis: *Omatia montgomeryi*; *Broomea ramosa.*

B. Cretaceous.

1. Lower Cretaceous.

(a) Upper Neocomian or Lower Aptian.

(i) Probably "Grierson Member" of Birdrong Formation, W.A., Meadow Station Bore No. 9.

The microplankton content is high with *Deflandrea cincta* as the dominant type. It includes:

Dinoflagellata: *Gonyaulax hyalodermopsis*; *Deflandrea cincta*; *Dingodinium cerviculum.*

Pterospermopsidae: *Pterospermopsis aureolata, P. eurypteris*; *Cymatiosphaera stigmata.*

(ii) "Grierson Member", Birdrong Formation, W.A., Wapet's Well No. 3 at 1390-1400 ft.

Unlike the sample from Meadow Station Bore No. 9, this deposit has a low microplankton content and high spore content and, on this account, has been given only a cursory examination. The types isolated include:

Dinoflagellata: *Dingodinium cerviculum.*

Hystrichosphaeridae: *Hystrichosphaeridium complex.*

Pterosphermopsidae: *Pterospermopsis aureolata.*

(b) Aptian.

(i) Muderong Shale, W.A., Wapet's Rough Range Well No. 8 at 3863-83 ft.

The microplankton includes:

Dinoflagellata: *Gonyaulax muderongensis*; *Dingodinium cerviculum*; *Palaeoperidinium* cf. *ventriosum*; *Muderongia mcwhaei.*

Hystrichosphaeridae: *Hystrichosphaeridium complex.*

(ii) Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 4 at 3532-50 ft.

The microplankton includes:

Dinoflagellata: *Dingodinium cerviculum.*

Hystrichosphaeridae: *Cannosphaeropsis fenestrata.*

Incertae Sedis: *Pseudoceratium tetracanthum.*

(iii) Rough Range Well No. 4 at 3350 ft.

From the occurrence of *Dingodinium cerviculum* and *Pseudoceratium tetracanthum* at this level, we judge that this deposit is of approximately the same age as the Windalia Radiolarite, which it overlies.

(iv) South Perth Formation, W.A., Attadale Bore at 809, 999 ft.

This deposit contains rather more spores than microplankton but the latter is sufficiently characteristic to suggest that its age is not younger than Aptian. Included in it are:

Dinoflagellata: *Gymnodinium attadalense*; *Gonyaulax hyalodermopsis, G. diaphanis* (999 ft.); *Dingodinium cerviculum*; *Muderongia mcwhaei*.

Pterospermopsidae: *Pterospermopsis eurypteris*.

Incertae Sedis: *Pareodina aphelia*; *Chlamydophorella nyei, C.* sp.

(v) Roma Series, North Queensland, Batavia Downs Station, Cape York Peninsula between 45 and 49 ft.

This deposit needs further investigation and a detailed comparison with the typical occurrence of the Roma Series in southern Queensland. The microplankton, which appears to contain a mixture of Aptian and Albian species, includes:

Dinoflagellata: *Dingodinium cerviculum*.

Hystrichosphaeridae: *Hystrichosphaeridium complex, H. parvispinum*; *Cyclonephelium compactum*.

Pterospermopsidae: *Pterospermopsis aureolata*.

Incertae Sedis: *Pseudoceratium turneri, P. tetracanthum*; *Chlamydophella nyei*; *Fromea amphora*.

(vi) Cootabarlow, S.A., Bore 2 at 1354 ft.

The age of the sample at this depth has been estimated by Dr. N. Ludbrook as Aptian on the basis of the contained arenaceous foraminifera (unpublished information, South Australian Department of Mines). The microplankton is in complete agreement with this finding. It includes the following types:

Dinoflagellata: *Dingodinium cerviculum*; *Muderongia mcwhaei*.

Hystrichosphaeridae: *Hystrichosphaeridium complex*.

Pterospermopsidae: *Pterospermopsis aureolata, P. eurypteris*.

(vii) Omati, Papua, I.E.C. Well 1, samples 9 and 5. The microplankton includes:

Dinoflagellata: *Dingodinium cerviculum*.

Hystrichosphaeridae: *Hystrichosphaeridium complex, H. anthophorum*.

Incertae Sedis: *Pseudoceratium tetracanthum*.

In containing *Dingodinium cerviculum* and *Pseudoceratium tetracanthum* these deposits are linked with the Windalia Radiolarite of Western Australia and the Roma Series of North Queensland.

(c) Albian.

(i) Gearle Siltstone (lower part), W.A., Wapet's Rough Range No. 7 at 2360-75 ft.; Rough Range No. 1 at 2000 and 2750 ft.

These deposits contain rich and varied microplankton assemblages. The spore content on the other hand is relatively low.

The microplankton includes:

Dinoflagellata: *Gonyaulax edwardsi*; *Palaeohystrichophora multispina.*

Hystrichosphaeridae: *Hystrichosphaeridium complex, H. recurvatum, H. siphoniphorum, H.* cf. *hirsutum* (Well No. 7 at 2360-75 ft.); *Coronifera oceanica* (Well No. 7 at 2360-75 ft.); *Cannosphaeropsis fenestrata* (Well No. 7 at 2360-75 ft.); *Cyclonephelium compactum.*

Insertae Sedis: *Pseudoceratium turneri* (Well No. 1 at 2750 ft.); *Ceratocystidiopsis ludbrooki* (Well No. 7 at 2360-75 ft.); *Odontochitina operculata*; *Fromea amphora*; *Chlamdophorella nyei.*

(ii) Cootabarlow, S.A., Bore 2 at 581-600 ft.

This portion of the Cootabarlow bore No. 2, as well as containing numerous spores and pollen grains, has a varied and well characterized microplankton content which is closely comparable with that of the lower portion of the Gearle Siltstone of Western Australia. Since the age attributed to the latter, on palaeontological grounds, is Albian there is a strong probability that the age of the Cootabarlow sediments in question is also Albian.

The microplankton includes:

Dinoflagellata: *Gonyaulax edwardsi, G. apionis*; *Palaeohystrichophora multispina.*

Hystrichosphaeridae: *Hystrichosphaeridium complex, H. pulcherrimum, H. recurvatum*; *Cyclonephelium compactum.*

Pterosperopsidae: *Pterospermopsis australiensis.*

Incertae Sedis: *Ceratocystidiopsis ludbrooki*; *Odontochitina operculata*; *Pseudoceratium turneri*; *Fromea amphora*; *Chlamydophorella nyei.*

(iii) Styx River Series, Queensland. Queensland Geological Survey Bore 21 at 327 ft.

The microplankton types recovered from this sample strongly support the Albian age originally suggested for the Styx Series by Walkom (1919). They include:

Dinoflagellata: *Gonyaulax edwardsi*; *Palaeohystrichophora pellifera.*

Hystrichosphaeridae: *Hystrichosphaeridium complex, H. recurvatum.*

Incertae Sedis: *Pseudoceratium turneri*; *Odontochitina operculata.*

(iv) Omati, Papua (Fig. 2).

Sample 4. The frequent occurrence of *Pseudoceratium turneri* in this deposit is suggestive of an Albian age.

Sample 2. The microplankton includes:

Dinoflagellata: *Gonyaulax* cf. *apionis*; *Palaeohystrichophora multispina.*

Hystrichosphaeridae: *Hystrichosphaeridium parvispinum, H.* cf. *hirsutum*; *Membranilarnax leptoderma.*

Incertae Sedis: *Dioxya armata*; *Odontochitina operculata*; *Pseudoceratium turneri.*

Several of these species occur in Australian Albian deposits.

(d) Probably Albian.

This estimation has been based on the contained microplankton assemblages, which agree fairly closely, as far as the main types are concerned, with that in the Gearle Siltstone (lower part), W.A.

(i) Near Gingin, W.A., Seismic shot hole L.8 at 240 ft.

Dinoflagellata: *Gonyaulax edwardsi.*

Hystrichosphaeridae: *Hystrichosphaeridium siphoniphorum*; *Cyclonephelium compactum.*

Incertae Sedis: *Fromea amphora*; *Chlamydophorella nyei.*

(ii) Near Gingin, W.A., Seismic shot hole B.2 at 230 ft.

Dinoflagellata: *Deflandrea parva*; *Gonyaulax edwardsi*; *Palaeohystrichophora dispersa.*

Hystrichosphaeridae: *Hystrichosphaeridium siphoniphorum*; *Cymatiosphaera pterota.*

Incertae Sedis: *Ceratocystidiopsis ludbrooki*; *Odontochitina operculata*: *Chlamydophorella nyei*; *Fromea amphora.*

(iii) North-east of Gingin, W.A., Moora bore between 86 and 170 ft.

This sample is highly carbonaceous with a preponderance of woody tissue, a rather well characterized microplankton assemblage and a low proportion of spores and pollen grains.

The microplankton includes:

Dinoflagellata: *Gonyaulax edwardsi*; *Palaeohystrichophora multispina*; *Hystrichodinium oligocanthum* Defl. and Cookson (1955).

Hystrichosphaeridae: *Hystrichosphaeridium complex, H. pulcherrimum* Defl. and Cookson (1955), *H. recurvatum*; *Coronifera oceanica*; *Cyclonephelium compactum.*

Incertae Sedis: *Pseudoceratium turneri; Odontochitina operculata*: *Chlamydophorella nyei*; *Fromea amphora.*

(iv) Osborne Park, W.A., King Edward Street bore between 265-95 ft.

Dinoflagellata: *Gonyaulax edwardsi*; *Palaeohystrichophora dispersa.*

Hystrichosphaeridae: *Hystrichosphaeridium siphoniphorum*; *Cyclonephelium compactum.*

Incertae Sedis: *Ceratocystidiopsis ludbrooki*; *Odontochitina operculata*; *Chlamydophorella nyei.*

(v) Subiaco, W.A., Water Bore at 358 ft.

The age of this deposit is uncertain. It is linked by the occurrence of *Deflandrea acuminata* with the upper Cenomanian part of the Gearle Siltstone, and by *Ceratocystidiopsis ludbrooki* with the lower Albian part of the Gearle Siltstone, but unfortunately the upper limit of the latter species and the lower limit of the former is not known. On the whole, the Subiaco deposit has more types in common with the lower part of the Gearle Siltstone than with the upper part, and it seems likely that its age approximates more closely to Upper Albian than to Lower Cenomanian.

The microplankton includes:

Dinoflagellata: *Deflandrea acuminata*; *Gonyaulax edwardsi*; *Palaeohystrichophora* cf. *multispina*.

Hystrichosphaeridae: *Hystrichosphaeridium siphoniphorum*; *Cannosphaeropsis fenestrata*.

Incertae Sedis: *Fromea amphora*; *Odontochitina operculata*; *Ceratocystidiopsis ludbrooki*.

2. Upper Cretaceous.

(a) Cenomanian to Lower Turonian. Gearle Siltstone (upper part), Wapet's Rough Range Well No. 5 at 1570 ft. and Well No. 8 at 1530-48 ft.

The microplankton, which at both these levels is moderately rich and varied with *Palaeohystrichophora infusorioides* of the French Cenomanian as the dominant type, includes:

Dinoflagellata: *Gymnodinium westralium*; *Deflandrea acuminata, D. parva*; *Gonyaulax edwardsi* (Well No. 5 at 1570 ft.); *Palaeohystrichophora infusorioides*.

Pterospermopsidae: *Cymatiosphaera pterota*.

Incertae Sedis: *Chlamydophorella nyei*; *Odontochitina operculata*; *Cyclodictyon paradoxos*; *Korojonia dubiosa* (Well No. 5 at 1570 ft.).

(b) Campanian to Lower Maestrichtian. Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4 at 1380-88 ft.

The most noticeable change in the microplankton content of this deposit is the appearance of three species of *Deflandrea* not observed in older sediments, and the apparent absence of *Gonyaulax* spp. which have been conspicuously present in all the lower horizons. The microplankton includes:

Dinoflagellata: *Gymnodinium westralium*; *Deflandrea pellucida, D. korojonensis, D. serratula*; *Palaeohystrichophora isodiametrica*.

Hystrichosphaeridae: *Hystrichosphaeridium recurvatum*.

Pterospermopsidae: *Cymatiosphaera pterota*.

Incertae Sedis: *Korojonia dubiosa*.

Conclusions

A. *Stratigraphical*

This study of the series of dated Upper Mesozoic samples, provided by West Australian Petroleum Pty. Ltd. from exploratory wells in the Exmouth Gulf area of Western Australia, clearly shows that the microplankton assemblages of the individual horizons and some of the species composing them, have a restricted vertical distribution. With one doubtful exception, none of the species occurring in the Middle and Upper Jurassic parts of the Dingo Siltstone of Cape Range extends into the Lower Cretaceous, provided the Neocomian or Lower Aptian age suggested for the Birdrong Formation is correct. A restriction of types likewise occurs in the Cretaceous sediments. Species such as *Dingodinium cerviculum, Muderongia mcwhaei* and *Pseudoceratium tetracanthum* have not been observed in beds younger than Aptian, while *Palaeohystrichophora multispina, Cyclonephelium compactum,*

Ceratocystidiopsis ludbrooki, Odontochitina operculata (Senonian in Europe) and *Pseudoceratium turneri* appear to be typical Albian species.

In addition, the discovery in Western Australia of types identical with ones occurring in European deposits of approximately the same ages, has reaffirmed the usefulness of microplankton in intracontinental correlations previously noted by Deflandre and Cookson (1955). Several examples can be cited:

(1) The species *Gymnodinium crystallinum*, *Gymnodinium luridum*, *Gonyaulax jurassica*, *Cannosphaeropsis aemula* and *Nannoceratopsis pellucida* which are associated together in the French Oxfordian, are also relatively common in the Upper Dingo Siltstone of Cape Range Wells Nos. 1 and 2, the age of which is thought to be Middle or Lower Kimeridgian. However, as only two of the species occurring in the Dingo Siltstone have been recorded from European Kimeridgian deposits, namely *Gonyaulax jurassica* and *Gonyaulax ambigua* from the Kimeridge clay of England (Downie, 1957) and *Gonyaulax ambigua* from Kimeridgian calcareous schists of France (Deflandre, 1941), the possibility of an Oxfordian age for the deposit in Cape Range Well No. 1 between 3900 and 4318 ft. and Well No. 2 between 3970 and 4527 ft. needs to be considered.

(2) Another close approximation is provided by the occurrence in Australian and Papuan deposits of *Pseudoceratium tetracanthum* from the upper Hauterivian (Neocomian) of north-western Germany (Gocht, 1957). This species is abundant in such Aptian deposits as the Windalia Radiolarite of Rough Range, W.A., the Roma Series of North Queensland, and the Papuan Omati samples 9, 5.

(3) The occurrence of *Coronifera oceanica* in the Gearle Siltstone (lower part) and in an Aptain deposit from northern Germany provides a further connection between the fossil microplankton of the northern and southern hemispheres.

(4) An even more exact correlation can be established between the French Cenomanian and the Cenomanian to Lower Turonian portion of the Gearle Siltstone (Rough Range Well No. 8 at 1530-48 ft. and Well No. 5 at 1570 ft.), by the occurrence in both of *Palaeohystrichophora infusorioides*, a species not at yet recorded from any other deposits.

Hitherto, no palaeontological correlations between Papuan and Western Australian Upper Mesozoic deposits have been made (Mr. J. N. Montgomery personal communication). Now, as the result of the present study, it can be shown that the Omati and Exmouth Gulf deposits have a number of microplankton types in common.

The upper samples of the Jurassic section of the Omati core (Nos. 24-35) agree with those of the upper Dingo Siltstone, W.A. (Cape Range Well No. 2, 3970-4527 ft.) in containing *Wanaea clathrata* together with *Gymnodinium crystallinum*, *Cannosphaeropsis aemula*, *Broomea ramosa* and *Nannoceratopsis pellucida*, whilst the lower samples (Nos. 36-42), like that of Cape Range Well No. 2 at 6032-60 ft., contain *Wanaea spectabilis*.

In the Cretaceous section of the Omati Core (sample No. 9, 5), the occurrence of *Dingodinium cerviculum* and *Pseudoceratium tetracanthum* supports a correlation with the Windalia Radiolarite of Rough Range and the Roma Series of North Queensland, while the occurrence of *Pseudoceratium turneri* in Sample 4 and of *Palaeohystrichophora* cf. *multispina*, *Hystrichosphaeridium* cf. *hirsutum* and *Odontochitina operculata* in Sample 2 permits correlation with the lower part of the Gearle Siltstone.

An opportunity to evaluate the role of microplankton in local stratigraphy has been afforded during the present investigation of Western Australian sediments, the age of several of which has been uncertain.

(1) The deposit between 1405 and 1427 feet in the Broome Artesian No. 3.

A difference of opinion exists regarding the age of this deposit, Teichert (1941, 1947) having suggested that it is Oxfordian to Lower Kimeridgian and Brunnschweiler (1954) that it is Tithonian. The microplankton, in containing the French Oxfordian species *Gymnodinium crystallinum, Gymnodinium luridum, Gonyaulax eisenacki*, sub. sp. *oligodentata* and *Cannosphaeropsis aemula*, as well as the Upper Dingo Siltstone species *Dingodinium jurassicum* and *Pareodinia aphelia*, supports an Oxfordian rather than a Tithonian age. A correlation with the Learmonth Formation (Rough Range No. 1 between 4376 and 4379 ft.) can be made on the basis of *Wanaea digitata*, a species that has not been found in any of the other deposits.

(2) South Perth Formation.

(a) Attadale bore between 809 and 999 ft.

Prior to the present investigations the age of this formation was not known precisely. Crespin (in Parr 1938) attributed a Lower Cretaceous age to the unit. The evidence of the contained microplankton is in agreement with this finding. Through the association in it of *Dingodinium cerviculum* and *Muderongia mcwhaei*, a correlation can be established with the Aptian Muderong Shale of W.A. and the siltstone intersected by the Cootabarlow (S.A.) No. 2 bore at 1354 ft., the age of which has been determined as Aptian by Dr. Nell Ludbrook (unpublished information, South Australian Department of Mines) on the basis of the abundant arenaceous foraminifera which it contains.

(b) Sample from between 265 and 295 ft., King Edward Street Bore, Perth.

In containing the species *Gonyaulax edwardsi, Hystrichosphaeridium siphoniphorum, Cyclonephelium compactum, Ceratocystidiopsis ludbrooki, Odontochitina operculata* and *Chlamydophorella nyei*, this deposit is closely linked with the lower part of the Gearle Siltstone, especially the sample from Well No. 7 between 2360 and 2375 ft., and is therefore almost certainly of Albian age.

(c) Deposit from Subiaco bore, W.A., at 358 ft.

The age of this deposit has been discussed earlier when the suggestion was made that it could be either Upper Albian or Lower Cenomanian. The occurrence in it of *Ceratocystidiopsis ludbrooki* suggests an Albian age while the presence of *Deflandrea acuminata* supports a Cenomanian age.

(3) Deposit from 230 ft., Seismic shot hole B.2, near Gingin.

This sample seems to have been a mixed one, but portion of it contains a microplankton assemblage approximating to that of the Gearle Siltstone (lower part) and the deposit from the King Edward Street Bore, more particularly to the latter in containing *Palaeohystrichophora dispersa* which has been found in only these two deposits. The age of this sample therefore appears to be Albian.

(4) Deposit from Wapet's Moora bore between 86 and 170 ft.

From the occurrence of *Pseudoceratium turneri* in association with such types as *Gonyaulax edwardsi, Palaeohystrichophora multispina, Cyclonephelium compactum* and *Odontochitina operculata*, all of which this sample holds in common

with the Albian deposit from Rough Range Well No. 1 at 2750 ft., it is estimated that the age of the Moora bore sample between 86 and 170 feet is Albian.

B. *Palaeontological*

One of the most striking features of the microplankton assemblages contained in the Upper Mesozoic deposits of Western Australia and Papua, is the great variety of types and the large number of new species included in them. This richness in new types may of course be only apparent, and when more work on microplankton has been published, some of these forms may prove to have a much wider distribution.

The relatively large number of Australian species of the genus *Deflandrea* is noteworthy in contrast to the single European species *D. phosphoritica* from the Lower Tertiary of Germany and Belgium. Previously five Tertiary (Deflandre and Cookson, 1955) and one upper Cretaceous species (Cookson, 1956) had been described from Australian deposits. Now six more have been distinguished making twelve in all, and the time range of the genus has been extended to Lower Cretaceous (Upper Neocomian or Lower Aptian).

The genus *Gonyaulax* is also strongly represented, the number of species described in this paper being by no means a complete representation of the forms present. This is particularly so with the Papuan types, which, with the exception of *Gonyaulax perforans*, and *Gonyaulax serrata* have been too imperfectly preserved for description.

The occurrence of *Wetzeliella irregularis* in the Upper Jurassic of Cape Range marks the first Mesozoic record of the genus *Wetzeliella*. Hitherto it has been recorded from Tertiary deposits only.

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TABLE 1

Distribution of some of the components of the microplankton in Australian, New Guinea and European Middle and Upper Jurassic deposits

Species	Middle to base of Upper Jurassic		Upper Jurassic						Kimeridgian	
	1	2	3	4	5	6	7	8	9	10
Gymnodinium crystallinum ..	+	+	+	−	+	−	+	+	−	−
Gymnodinium luridum	−	−	+	−	+	−	−	+	−	−
Gonyaulax ambigua	−	−	+	?	−	−	+	−	+	+
Gonyaulax jurassica	+	+	+	+	+	−	−	+	+	−
Dingodinium jurassicum ..	−	−	+	−	+	+	−	−	−	−
Nannoceratopsis pellucida ..	−	−	+	−	+	−	+	−	−	−
Cannosphaeropsis aemula ..	−	+	+	−	+	−	+	+	−	−
Cannosphaeropsis filamentosa ..	+	+	+	+	−	−	−	−	−	−
Cannosphaeropsis mirabilis ..	−	−	−	−	−	−	+	−	−	−
Wanaea clathrata	−	−	+	−	−	−	+	−	−	−
Wanaea spectabilis	−	+	−	−	−	+	−	−	−	−
Wanaea digitata	−	−	−	+	+	−	−	−	−	−
Broomea ramosa	+	−	+	−	+	−	+	−	−	−
Broomea simplex	−	−	−	−	−	+	+	−	−	−
Pareodinia aphelia	+	+	+	+	+	−	−	−	−	−

1. Dingo Siltstone, Cape Range Well 1, 6365-83 ft.
2. Dingo Siltstone, Cape Range Well 2, 6032-60 ft.
3. Dingo Siltstone (upper part), Cape Range Well 2, 3970-91 ft.
4. Learmonth formation, Rough Range Well 1, 4376-79 ft.
5. Broome Bore at 1405-37 ft.
6. Omati, Well 1, Samples 36-42.
7. Omati, Well 1, Samples 19-35.
8. Villers, sur/Mer, France (Oxfordian).
9. Kimeridge, England.
10. Orbagnoux, France.

TABLE 2

Distribution of some of the components of the microplankton in Australian and New Guinea Cretaceous deposits

Species	Lower Cretaceous																Upper Cretaceous		
	Neocomian		Aptian						Albian								Cenomanian		Campanian
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Deflandrea acuminata	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	−
Deflandrea cincta	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Gonyaulax edwardsi	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	−
Dingodinium cerviculum	+	−	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−
Palaeohystrichophora multispina	−	−	−	−	−	−	−	−	−	+	−	+	−	−	+	−	−	−	−
Palaeohystrichophora dispersa	−	−		−	−	−	−	−	−	−	−	−	−	+	−	+	−	−	−
Muderongia mcwhaei	−	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
Hystrichosphaeridium complex	+	−	−	+	+	−	−	+	+	+	+	+	−	−	+	−	−	−	−
Hystrichosphaeridium recurvatum	−	−	−	−	−	−	−	−	+	+	+	+	−	+	+	−	−	−	+
Hystrichosphaeridium siphoniferum	−	−	−	−	−	−	−	−	−	−	−	+	+	+	−	+	−	+	−
Cyclonephelium compactum	−	−	−	−	−	−	−	+	+	+	−	+	+	−	+	+	−	−	−
Pseudoceratium tetracanthum	−	−	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−
Pseudoceratium turneri	−	−	−	−	−	−	−	+	?	+	+	+	−	−	+	−	−	−	−
Ceratocystidiopsis ludbrooki	−	−	−	−	−	−	−	−	−	+	−	+	−	+	−	+	−	+	−
Odontochitina operculata	−	−	−	−	−	−	−	−	+	+	+	+	−	+	+	+	+	+	−
Fromea amphora	−	−	−	−	−	−	−	+	+	+	−	+	+	+	+	−	−	+	−
Chlamydophorella nyei	−	−	+	−	−	−	−	+	+	+	−	+	+	+	+	+	+	+	−

1. "Wapets' Grierson", Well No. 3, W.A., between 1390–1400 ft.
2. "Grierson Member", Birdrong Formation, Meadow Bore No. 9, W.A.
3. South Perth Formation, Attadale Bore at 809 ft.*
4. Muderong Shale, W.A.
5. Windalia Radiolarite, W.A.
6. Cootabarlow Bore No. 2, S.A., at 1354 ft.
7. Omati, Papua, Samples, No. 9 and 5.
8. Roma Series, Q'land, Batavia Downs Station Well at 45-49 ft.
9. Onepah Well, N.S.W.
10. Cootabarlow Bore No. 2, S.A., at 581 ft.
11. Styx River Series, Q'land, Bore 21 at 327 ft.
12. Gearle Siltstone (lower part), W.A.
13. *Gingin, W.A., shot hole L.8 at 240 feet.
14. *Gingin, W.A., shot hole B.2 at 230 feet.
15. *Moora Bore, W.A., between 86-170 feet.
16. *King Edward Street Bore, W.A., 265-95 ft.
17. Gearle Siltstone (upper part), W.A.
18. *Subiaco Bore, W.A., at 358 ft.
19. Korojon Calcarenite, W.A.

* The age of deposits so marked has been based on the composition of the microplankton and is only approximate.

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Explanation of Plates

All photographs are from untouched negatives.

Registered numbers in the palaeobotanical collection of the National Museum of Victoria are given.

PLATE I

Fig. 1.—*Gymnodinium crystallinum* Defl. Broome, Artesian Bore No. 3, W.A., 1405-27 ft. × 550. P 17232.

Fig. 2.—*Gymnodinium crystallinum*. Dingo Siltstone, W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. × 300. P 17233.

Fig. 3.—*Gymnodinium luridum* Defl. Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1, 3825-40 ft. × *c.* 400. P 17234.

Fig. 4.—*Gymnodinium luridum*. Dingo Siltstone, W.A., Wapet's Cape Range Well No. 1, 3825-40 ft. × *c.* 370. P 17235.

Fig. 5.—*Gymnodinium crystallinum* sp. nov. Dingo Silstone (middle), W.A., Wapet's Cape Range Well No. 1, 6365-83 ft. × *c.* 350. P 17236.

Fig. 6.—*Gymnodinium parvimarginatum* sp. nov. Holotype, Broome, Artesian Bore No. 3, W.A., 1405-27 ft. × 400. P 17237.

Fig. 7.—*Gymnodinium attadalense* sp. nov. Holotype, South Perth Formation, W.A., Attadale Artesian Bore at 809 ft. × 400. P 17238.

Fig. 8.—*Gymnodinium nelsonense* Cookson. Korojon Calcarenite, Wapet's Rough Range Well No. 4, 1380-88 ft. × *c*. 550. P 17239.

Fig. 9.—*Gymnodinium westralium* sp. nov. Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4, 1380-88 ft. × *c*. 580. P 17240.

Fig. 10.—*Dingodinium jurassicum* sp. nov. Holotype, Broome Artesian Bore No. 3, W.A., 1405-27 ft. × *c*. 550. P 17241.

Fig. 11.—*Dingodinium jurassicum*. Sideview of a Paratype. Dingo Siltstone W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. × *c*. 560. P 17242.

Fig. 12.—*Dingodinium cerviculum* sp. nov. South Perth Formation, W.A., Attadale Artesian Bore at 700 ft. × 400. P 17243.

Figs. 13, 14.—*Dingodinium cerviculum*. Probably "Grierson Member", Birdrong Formation, W.A., Meadow Station Artesian Bore No. 9 Fig. 13 × c. 350. P 17267. Fig. 14, holotype × *c*. 450. P 17244.

Plate II

Fig. 1.—*Gonyaulax perforans* sp. nov. Holotype, Omati, Papua, I.E.C. Well No. 1, Sample 31 × *c*. 300. P 17256.

Fig. 2.—*Gonyaulax perforans*. Omati, Papua, Well 1, Sample 31 × *c*. 300. P 17257.

Figs. 3, 4.—*Gonyaulax perforans*. Two highly ornamented specimens. Omati, Papua, Sample 31 Fig. 3, dorsal surface × 350. P. 17258. Fig. 4, ventral surface showing longitudinal furrow × 350. P 17256.

Fig. 5.—*Gonyaulax scotti* sp. nov. Holotype, Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. × *c*. 300. P 17260.

Fig. 6.—*Gonyaulax scotti*. Ventral view of a paratype. Dingo Siltstone (upper part), Wapet's Cape Range Well No. 2, 3970-91 ft. × *c*. 270. P 17261.

Fig. 7.—*Gonyaulax perforans*. Hypotheca viewed from below, Omati, Papua, Well 1, Sample 31, × 360. P 17262.

Fig. 8.—*Gonyaulax perforans*. Portion of wall showing perforated external ornament, Omati. Papua, Sample 31, × *c*. 350. P 17263.

Fig. 9.—*Gonyaulax jurassica* Defl. Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2, 6032-60 ft. × *c*. 380. P 17264.

Fig. 10.—*Gonyaulax jurassica*. Learmonth Formation, Wapet's Rough Range Well No. 1, 4376-79 ft. × *c*. 560. P 17265.

Fig. 11.—*Gonyaulax eisenacki* Defl. sub-species *oligodentata* n.sub.sp. Broome, W.A., Artesian Bore No. 3, 1405-27 ft. × *c*. 530. P 17266.

Plate III

Fig. 1.—*Gonyaulax ambigua* Defl. Dingo Siltstone (upper portion), W.A., Wapet's Cape Rough Range Well No. 2, 3825-40 ft. × *c*. 400. P 17439.

Fig. 2.—*Gonyaulax serrata* sp. nov. Holotype, Omati, Papua, I.E.S. Well 1, Sample 20 (Fig. 2). × *c*. 400. P 17446.

Fig. 3.—*Gonyaulax muderongensis* sp. nov. Holotype, Muderong Shale, W.A., Wapet's Rough Range Well No. 8, 3863-83 ft. × *c*. 340. P 17488.

Fig. 4.—*Gonyaulax muderongensis*. Paratype, Muderong Shale, W.A., Wapet's Rough Range Well No. 8, 3863-83 ft. × *c*. 420. P 17489.

Fig. 5.—*Gonyaulax edwardsi* sp. nov. Paratype, Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 1 at 2000 ft. × *c*. 300. P 17493.

Fig. 6.—*Gonyaulax edwardsi*. Holotype, Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 1 at 2000 ft. × *c*. 350. P 17440.

Fig. 7.—*Gonyaulax apionis*. Cootabarlow, S.A., Bore 2 at 600 ft. × *c*. 400. P 17441.

Fig. 8.—*Gonyaulax* sp. Near Gingin, W.A., Seismic shot hole L.8 at 240 ft. × *c*. 300. P 17442.

Fig. 9.—*Gonyaulax* sp. Gearle Siltstone, W.A., Wapet's Rough Range Well No. 7, 2360-75 ft. × *c*. 270. P 17278.

Fig. 10.—*Palaeoperidinium* cf. *ventriosum* (O. Wetzel). Muderong Shale, W.A., Wapet's Rough Range Well No. 8, 3863-83 ft. × *c*. 300. P 17443.

Figs. 11, 12.—*Gonyaulax hyalodermopsis* sp. nov. Holotype, South Perth Formation, W.A., Attadale Bore at 809 ft. Fig. 11, ventral view. Fig. 12, Dorsal view, × *c.* 400. P 17434.

Figs. 13, 14.—*Gonyaulax diaphanis* sp. nov. Holotype, South Perth Formation, Attadale Bore at 999 ft. Fig. 13, ventral view, × *c.* 270. Fig. 14, Dorsal view, × *c.* 300. P 17437.

Plate IV

Figs. 1, 2.—*Deflandrea cincta* sp. nov. Paratypes, probably "Grierson Member" of Birdrong Formation, W.A., Meadow Station, Bore No. 9. Fig. 1, × *c.* 400. P 17255. Fig. 2, × *c.* 450. P 17245.

Fig. 3.—*Deflandrea cincta.* Holotype, Meadow Station, Bore No. 9. × *c.* 400. P 17246.

Fig. 4.—*Deflandrea serratula* sp. nov. Holotype, Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 5 at 1570 ft. × *c.* 580. P 17247.

Fig. 5.—*Deflandrea acuminata* sp. nov. Holotype, Gearle Formation (upper portion), W.A., Wapet's Rough Range Well No. 5 at 1570 ft. × *c.* 580. P 17248.

Fig. 6.—*Deflandrea acuminata.* Internal capsule with portion of outer membrane, Wapet's Rough Range Well No. 5 at 1570 ft. × *c.* 550. P 17249.

Figs. 7, 8.—*Deflandrea acuminata.* Fig. 7, Rough Range Well No. 5 at 1570 ft. × *c.* 400. P 17250. Fig. 8, Subiaco, W.A., Water Bore No. 8 at 358 ft. × *c.* 600. P 17251.

Fig. 9.—*Deflandrea pellucida* sp. nov. Holotype, Nelson Bore, Vic., at 3874 ft. × *c.* 428. P 16237.

Fig. 10.—*Deflandrea korojonensis* sp. nov. Holotype, Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4, 1380-88 ft. × *c.* 600. P 17252.

Fig. 11.—*Deflandrea korojonensis.* Paratype, Wapet's Rough Range Well No. 4, 1380-88 ft. × *c.* 325. P 17253.

Fig. 12.—*Deflandrea parva* sp. nov. Holotype, Gingin, W.A., Seismic shot hole B.1 at 230 ft. × *c.* 525. P 17254.

Fig. 13.—*Deflandrea parva.* Paratype, Gingin, Seismic shot hole B.1 at 230 ft. × *c.* 400. P 17254.

Plate V

Fig. 1.—*Pseudoceratium tetracanthum* Gocht. Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 7, 3532-50 ft. × *c.* 300. P 17268.

Figs. 2, 4.—*Pseudoceratium turneri* sp. nov. Paratype, Omati, Papua, I.E.C. Well No. 1, Sample 4. Fig. 2, × *c.* 330. P 17269. Fig. 4, × *c.* 320. P 17271.

Fig. 3.—*Pseudoceratium turneri.* Holotype, Gearle Siltstone, W.A., Rough Range No. 1 at 2750 ft. × *c.* 420. P 17270.

Fig. 5.—*Pseudoceratium turneri.* Paratype, Roma Series, North Queensland Well on Batavia Downs Station, 45-49 ft. × *c.* 300. P 17272.

Fig. 6.—*Pseudoceratium turneri.* A detached apical horn, Gearle Siltstone, W.A., Rough Range No. 1 at 2750 ft. × *c.* 350. P 17270.

Fig. 7.—*Ceratocystidiopsis ludbrooki* sp. nov. Holotype, Cootabarlow, S.A., Bore at 581 ft. × *c.* 300. P 17273.

Fig. 8.—*Ceratocystidiopsis ludbrooki.* Paratype, Gearle Siltstone (lower part), W.A. Wapet's Rough Range Well No. 7, 2360-75 ft. × *c.* 300. P 17274.

Fig. 9.—*Hystrichodinium amphiacanthum* sp. nov. Omati, Papua, I.E.C. Well 1, Sample 19. × *c.* 300. P 17275.

Figs. 10, 11.—*Fromea amphora* sp. nov. Fig. 10, Holotype, Cootabarlow, S.A., Bore 2 at 581 ft. × *c.* 380. P 17276. Fig. 11, Paratype, Gingin, W.A., Seismic shot hole L.8 at 240 ft. × *c.* 420. P 17277.

Plate VI

Fig. 1.—*Muderongia mcwhaei* sp. nov. Paratype, Muderong shale, W.A., Wapet's Rough Range Well No. 8, 3863-81 ft. × *c.* 300. P 17278.

Fig. 2.—*Muderongia mcwhaei.* Holotype, Cootabarlow, S.A., Bore 2 at 1354 ft. × *c.* 320. P 17279.

Figs. 3, 4, 5.—*Muderongia mcwhaei.* Paratypes showing "girdle". Fig. 3, Muderong shale, W.A., × *c.* 400. P 17280. Fig. 4, Muderong shale, W.A., × *c.* 350. Fig. 5, South Perth Formation, W.A., Attadale Artesian Bore at 809 ft. × *c.* 560. P 17282.

Fig. 6.—*Broomea ramosa* sp. nov. Antapical region of a Paratype showing the longitudinal subdivision of the antapical horns, Broome, W.A., Artesian Bore No. 3, 1405-27 ft. × *c.* 400. P 17283.

Figs. 7, 8.—*Broomea ramosa*. Fig. 7, Holotype, Broome, W.A., Artesian Bore No. 3, 1405-27 ft. × *c*. 300. P 17284. Fig. 8, Paratype focused to show "girdle", Broome Artesian Bore No. 3, 1405-27 ft. × *c*. 350. P 17285.

Fig. 9.—*Broomea simplex*. Holotype, Omati, Papua, I.E.C. Well No. 1, Sample 24 (Table 1). × *c*. 200. P 17286.

Figs. 10, 11.—*Pyxidiella pandora* sp. nov. Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. Fig. 10, Holotype, × *c*. 600. P 17287. Fig. 11, Paratype, × *c*. 600. P 17288.

Plate VII

Fig. 1.—*Cannosphaeropsis fenestrata* Defl. and Cookson. Windalia Radiolarite, W.A., Wapet's Rough Range Well No. 4, 3532-50 ft. × *c*. 390. P 17259.

Figs. 2, 3.—*Cannosphaeropsis fenestrata*. Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7, 2360-75 ft. Fig. 2 × *c*. 300. P 17278. Fig. 3 × *c*. 350. P 17492.

Fig. 4.—*Cannosphaeropsis utinensis filifera* sub-sp. nov. Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4, 1380-88 ft. × *c*. 400. P. 17280.

Fig. 5.—*Cannosphaeropsis aemula* Defl. Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. × 300. P 17281.

Figs. 6, 7.—*Cannosphaeropsis aemula* sub. sp. *integra* sub-sp. nov. Dingo Siltstone (middle part), W.A., Wapet's Cape Range Well No. 1, 6365-83 ft. Fig. 6 × 420. P 17490. Fig. 7 × 400. P 17445.

Figs. 8, 9.—*Cannosphaeropsis filamentosa* sp. nov. Fig. 8, Paratype, Dingo Siltstone (upper part), Wapet's Cape Range Well No. 2, 6030-60 ft. × *c*. 430. P 17444. Fig. 9, Holotype, Learmonth Formation, W.A., Wapet's Rough Range Well No. 1, 4376-79 ft. × *c*. 400. P 17446.

Plate VIII

Fig. 1.—*Cannosphaeropsis filamentosa*. Learmonth Formation, W.A., Wapet's Rough Range Well No. 1, 4376-79 ft. × *c*. 480. P 17438.

Fig. 2.—*Cannosphaeropsis filamentosa*. Dingo Siltstone, W.A., Wapet's Cape Range Well No. 2, 6032-60 ft. × *c*. 400. P 17447.

Figs. 3, 5.—*Cannosphaeropsis mirabilis* sp. nov. Omati, Papua, I.E.C. Well 1, Sample 19 (Fig. 2). Fig. 3, Holotype, × *c*. 400. P 17448. Fig. 5, Paratype showing linear arrangement of processes, × *c*. 400. P 17450.

Fig. 4.—*Cannosphaeropsis mirabilis*. Omati, Papua, Well 1, Sample 20 (Fig. 2). × *c*. 600. P 17449.

Fig. 6.—*Omatia pisciformis* sp. nov. Omati, Papua, Well 1, Sample 20 (Fig. 2), Holotype, × *c*. 300. P 17451.

Figs. 7, 8.—*Omati montgomeryi* sp. nov. Omati, Papua, Well 1, Sample 19 (Fig. 2). Fig. 7, A Paratype × *c*. 400. P 17452. Fig. 8, Holotype × *c*. 400. P 17453.

Fig. 9.—*Omatia montgomeryi*. Omati, Papua, Well 1, Sample 20 (Fig. 2). × *c*. 600.

Figs. 10, 12.—*Hystrichosphaeridium parvispinum* sp. nov. Omati, Papua, I.E.C. Well 1, Sample 5 (Fig. 2), Paratypes. Fig. 10, × *c*. 600. P 17481. Figs. 11, 12, × *c*. 400. P 17454, P 17455.

Plate IX

Fig. 1.—*Wanaea spectabilis* Defl. and Cookson. Paratype, Omati, Papua, I.E.C. Well 1, Sample 40 (Fig. 2). × *c*. 400. P 17297.

Fig. 2.—*Wanaea digitata* sp. nov. Holotype, Learmonth Formation, W.A., Wapet's Rough Range Well No. 1, 4376-79 ft. × *c*. 280. P 17298.

Figs. 3–5.—*Wanaea digitata*. Paratype, Broome, W.A., Artesian Bore No. 3, 1405-27 ft. Fig. 3, × *c*. 280. P 17299 Figs. 4, 5, × *c*. 400.

Fig. 6.—*Wanaea clathrata* sp. nov. Holotype, Dingo Siltstone (upper part), Wapet's Cape Range Well No. 2, 3970-91 ft. × 300. P 17230.

Figs. 7, 8.—*Wanaea clathrata*. Paratypes, Dingo Siltstone (upper part), Wapet's Cape Range Well No. 2, 3970-91 ft. Fig. 7 × *c*. 280. P 17301. Fig. 8 × *c*. 300. P 17302.

Figs. 9 and 13.—*Pterospermopsis eurypteris* sp. nov. Fig. 9, Paratypes, South Perth Formation, W.A., Attadale Bore at 809 ft. × *c*. 280. P 17303. Fig. 13, Holotype, Cootabarlow, S.A., Bore 2 at 1354 ft. × *c*. 300. P 17304.

Figs. 10–11.—*Pterospermopsis aureolata* sp. nov. Probably "Grierson Member", Birdrong Formation, W.A., Meadow Station Bore No. 9. Fig. 10, Paratype × *c*. 300. P 17305. Fig. 11, Holotype × *c*. 300. P 17306.

Fig. 12.—*Pterospermopsis aureolata.* Roma Series, North Queensland, Well on Batavia Downs Station, 45149 ft. × *c.* 300. P 17456.

Fig. 14.—*Cymatiosphaera stigmata.* "Grierson Member", Birdrong Formation, W.A., Meadow Station Bore 9. Holotype × *c.* 400. P 17435.

PLATE X

Figs. 1, 2.—*Wetzeliella irregularis* sp. nov. Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. Fig. 1, Holotype × *c.* 470. P 17301. Fig. 2, Paratype × *c.* 430. P 17436.

Figs. 3, 4.—*Leiofusa jurassica* sp. nov. Dingo Siltstone (upper part), Wapet's Cape Range Well No. 1, 3825-40 ft. and Well No. 2, 3970-91 ft. Fig. 3 × *c.* 570. P 17457. Fig. 4, Holotype × *c.* 800. P 17485.

Figs. 5, 6.—*Nannoceratopsis pellucida* Defl. Fig. 5, Dingo Siltstone (upper part), Wapet's Cape Range Well No. 2, 3970-91 ft. × c. 560. P 17458. Fig. 6, Omati, Papua, I.E.C. Well 1, Sample 31 (Fig. 2) × *c.* 420. P 17263.

Figs. 7, 9.—*Membranilarnax leptoderma* sp. nov. Omati, Papua, I.E.C. Well 1, Sample 2 × c. 420. Fig. 7, P 17460. Fig. 9, P 17461.

Fig. 8.—*Membranilarnax* sp. Omati, Papua, Well 6, Sample 2, × *c.* 420. P 17460.

Fig. 10.—*Palaeohystrichophora infusorioides* Defl. Gearle Siltstone (upper part), W.A., Wapet's Rough Range Well No. 8, 1530-48 ft. × 500. P 17462.

Fig. 11.—*Palaeohystrichophora pellifera* sp. nov. Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 1, at 2000 ft. × 550. P 17459.

Fig. 12.—*Palaeohystrichophora dispersa* sp. nov. Near Gingin, W.A., Seismic shot hole B.2 at 230 ft. × 630. P 17463.

Fig. 13.—*Palaeohystrichophora multispina* Defl. and Cookson. Gearle Siltstone (lower part) Rough Range Well No. 7, 2360-75 ft. × *c.* 525. P 17492.

Fig. 14.—*Palaeohystrichophora dispersa.* Near Gingin, W.A., Seismic shot hole B.2 at 230 ft. × *c.* 400. P 17463.

PLATE XI

Fig. 1.—*Chlamydophorella nyei*, sp. nov. Holotype, Roma Series, North Queensland, Batavia Downs Station Well, Cape York Peninsula, 45-49 ft. × *c.* 700. P 17464.

Fig. 2.—*Chlamydophorella nyei.* Paratype, Gingin area, W.A., Seismic shot hole L.8 at 240 ft. × *c.* 540. P 17465.

Fig. 3.—*Chlamydophorella nyei.* Polar view, Gearle Siltstone (lower portion), W.A., Wapet's Rough Range Well No. 7, 2360-75 ft. × *c.* 600. P 17491.

Fig. 4.—*Chlamydophorella?* sp. South Perth Formation, W.A., Attadale Bore at 999 ft. × *c.* 500. P 17437.

Figs. 5, 6.—*Hystrichosphaeridium* cf. *hirsutum.* Gearle Siltstone (lower part), Wapet's Rough Range Well No. 7, 2360-75 ft. Fig. 5, × *c.* 400. P 17466. Fig. 6, × *c.* 600. P 17467.

Fig. 7.—*Cymatiosphaera pterota* sp. nov. Holotype, Gingin area, W.A., Seismic shot hole B.2 at 230 ft. × *c.* 530. P 17254.

Figs. 8, 10.—*Hystrichosphaeridium siphoniphorum* sp. nov. Gingin area, W.A., Seismic shot hole B.2 at 230 ft. Fig. 8, Holotype × *c.* 400. P 17468. Fig. 10, Paratype × *c.* 400. P 17469.

Fig. 9.—*Hystrichosphaeridium siphoniphorum.* Paratype showing "lid" of pylome partially open, Subiaco, W.A., Artesian Bore at 358 ft. × *c.* 435. P 17470.

Fig. 11.—*Dioxya armata* sp. nov. Holotype, Omati, Papua, I.E.C. Well 1. Sample 2 × *c.* 600. P 17461.

Fig. 12.—*Hystrichosphaeridium anthophorum* sp. nov. Holotype, Omati, Papua, I.E.C. Well 1, Sample 5 × *c.* 275. P 17471.

Fig. 13.—*Hystrichosphaeridium anthophorum* sp. nov. Omati, Papua, I.E.C. Well 1, Sample 27 × *c.* 460. P 17473.

PLATE XII

Fig. 1.—*Cyclodictyon paradoxos* sp. nov. Holotype, Gearle Siltstone (upper part), Wapet's Rough Range Well No. 5 at 1570 ft. × *c.* 400. P 17474.

Fig. 2.—*Cyclodictyon paradoxos.* Paratype, Gearle Siltstone (lower part), Wapet's Rough Range Well No. 8, 1530-48 ft. × *c.* 400. P 17475.

Fig. 3.—*Pareodinia aphelia* sp. nov. Paratype, South Perth Formation, W.A., Attadale Bore at 809 ft. × *c.* 400. P 17476.

Fig. 4.—*Pareodinia aphelia.* Holotype, Learmonth Formation, W.A., Wapet's Rough Range Well No. 1, 4376-79 ft. × *c.* 400. P 17477.

Fig. 5.—*Coronifera oceanica* sp. nov. Gearle Siltstone (lower part), Wapet's Rough Range Well No. 7, 2360-78 ft. × *c.* 340. P 17479.

Fig. 6.—*Coronifera oceanica.* Holotype, Gearle Siltstone (lower part), Wapet's Rough Range Well No. 7, 2360-78 ft. × *c.* 400. P 17478.

Fig. 7.—*Cyclonephelium compactum* Defl. and Cookson. Cootabarlow, S.A., Bore No. 2 at 581 ft. × *c.* 440. P 17273.

Fig. 8.—*Cyclonephelium compactum.* Gearle Siltstone (lower part), W.A., Wapet's Rough Range Well No. 7, 2360-75 ft. × *c.* 400. P 17480.

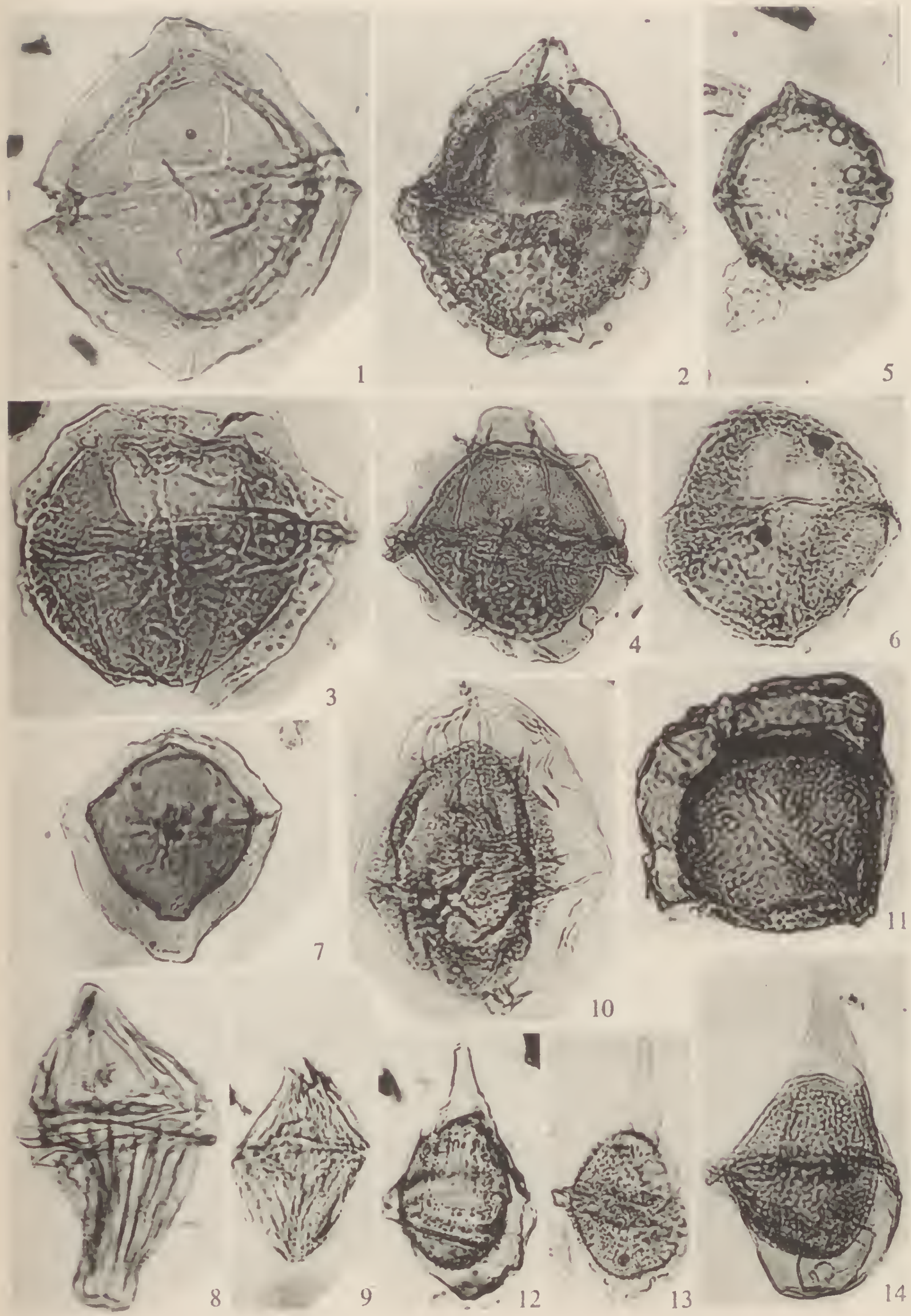
Fig. 9.—*Pareodinia aphelia* sp. nov. Dingo Siltstone (upper part), W.A., Wapet's Cape Range Well No. 2, 3970-91 ft. × *c.* 500. P 17481.

Fig. 10.—*Hystrichosphaeridium complex* (White). Muderong Shale, W.A., Wapet's Rough Range Wall No. 8, 3863-81 ft. × *c.* 425. P 17487.

Figs. 11, 12.—*Palaeohystrichophora isodiametrica* sp. nov. Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4, 1380-88 ft. Fig. 11, a Paratype × *c.* 470. P 17482. Fig. 12, Holotype × *c.* 430. P 17483.

Fig. 13.—*Korojonia dubiosa* sp. nov. Korojon Calcarenite, W.A., Wapet's Rough Range Well No. 4, 1380-88 ft. × *c.* 420. P 17486

List of Species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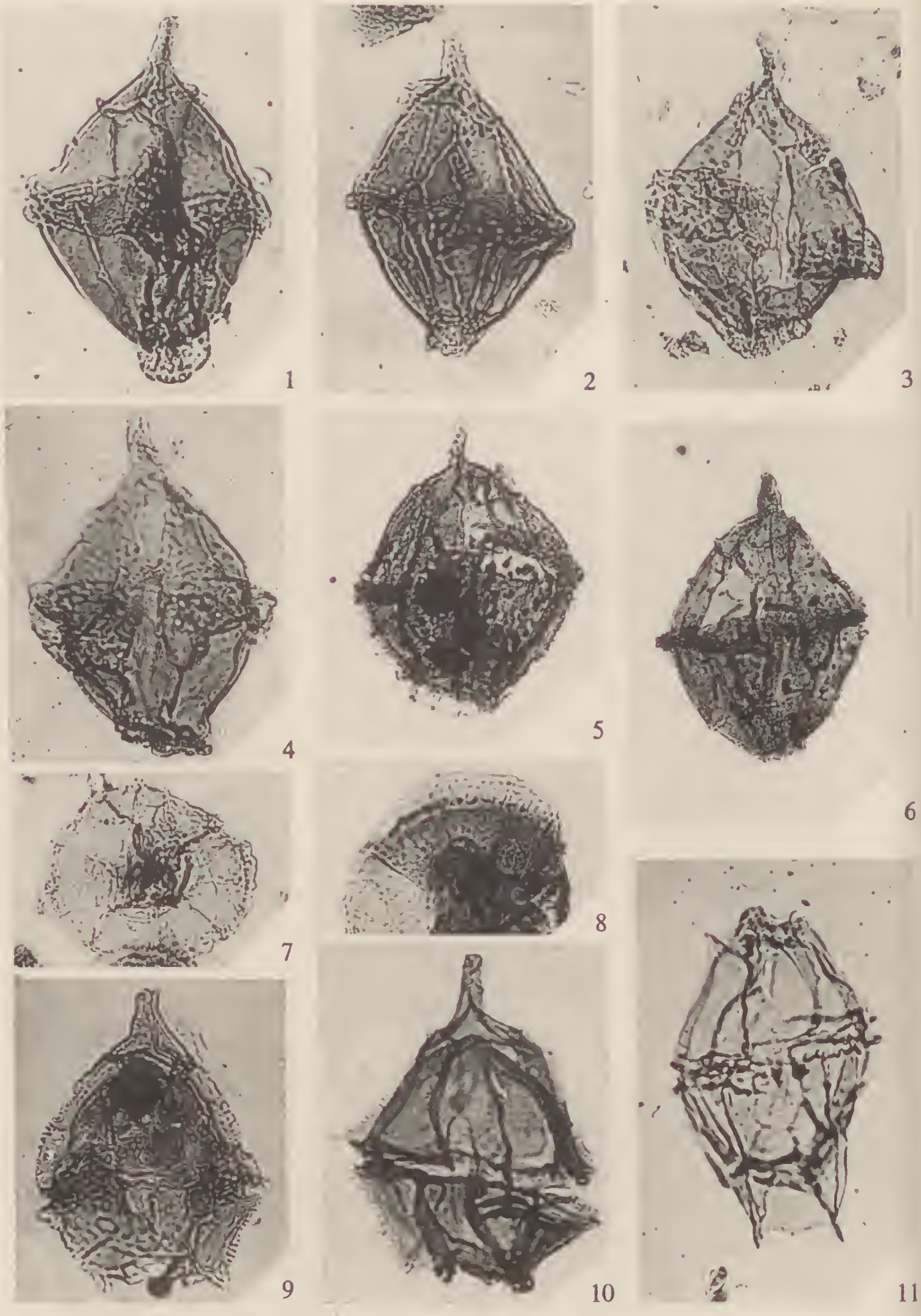
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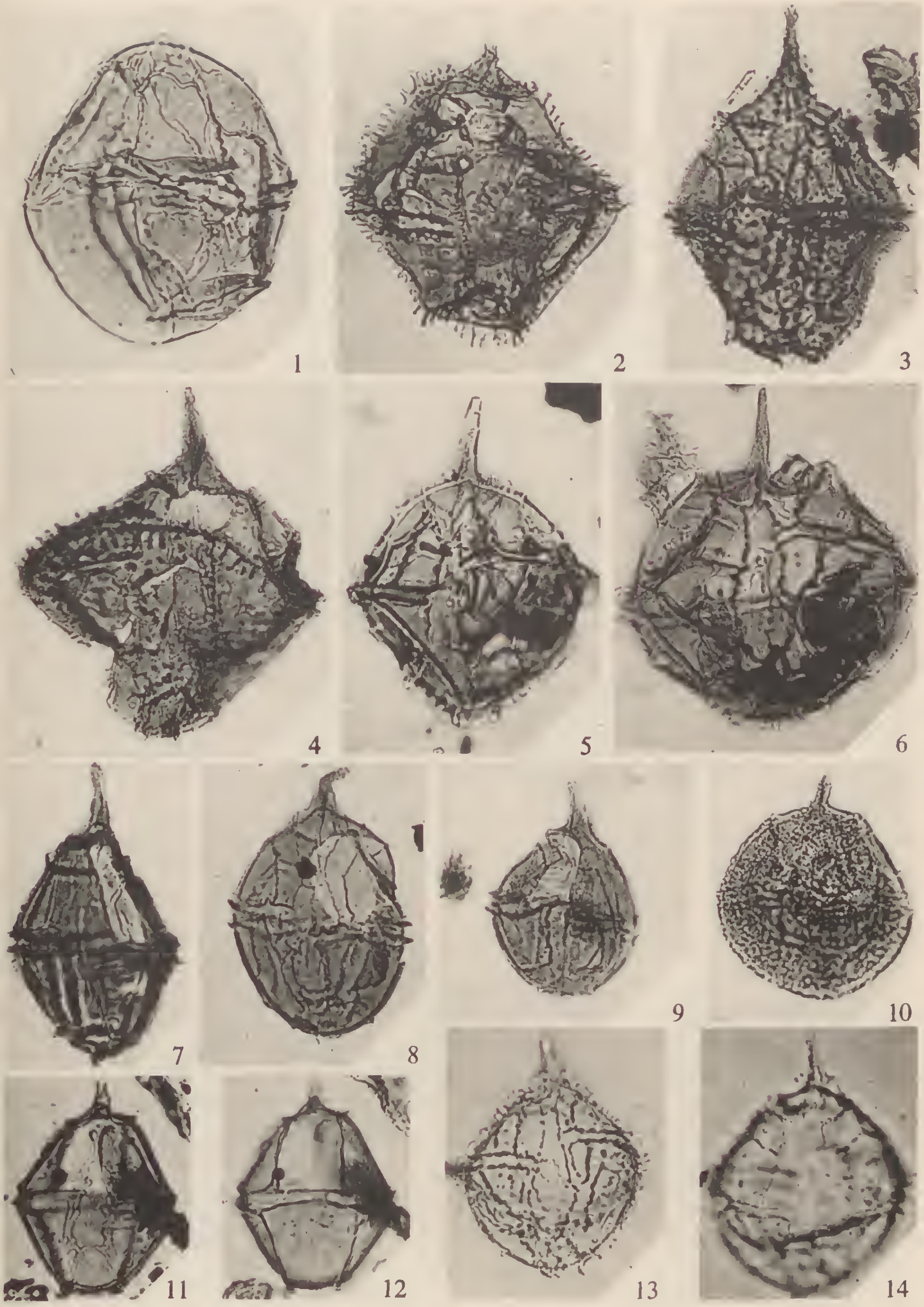
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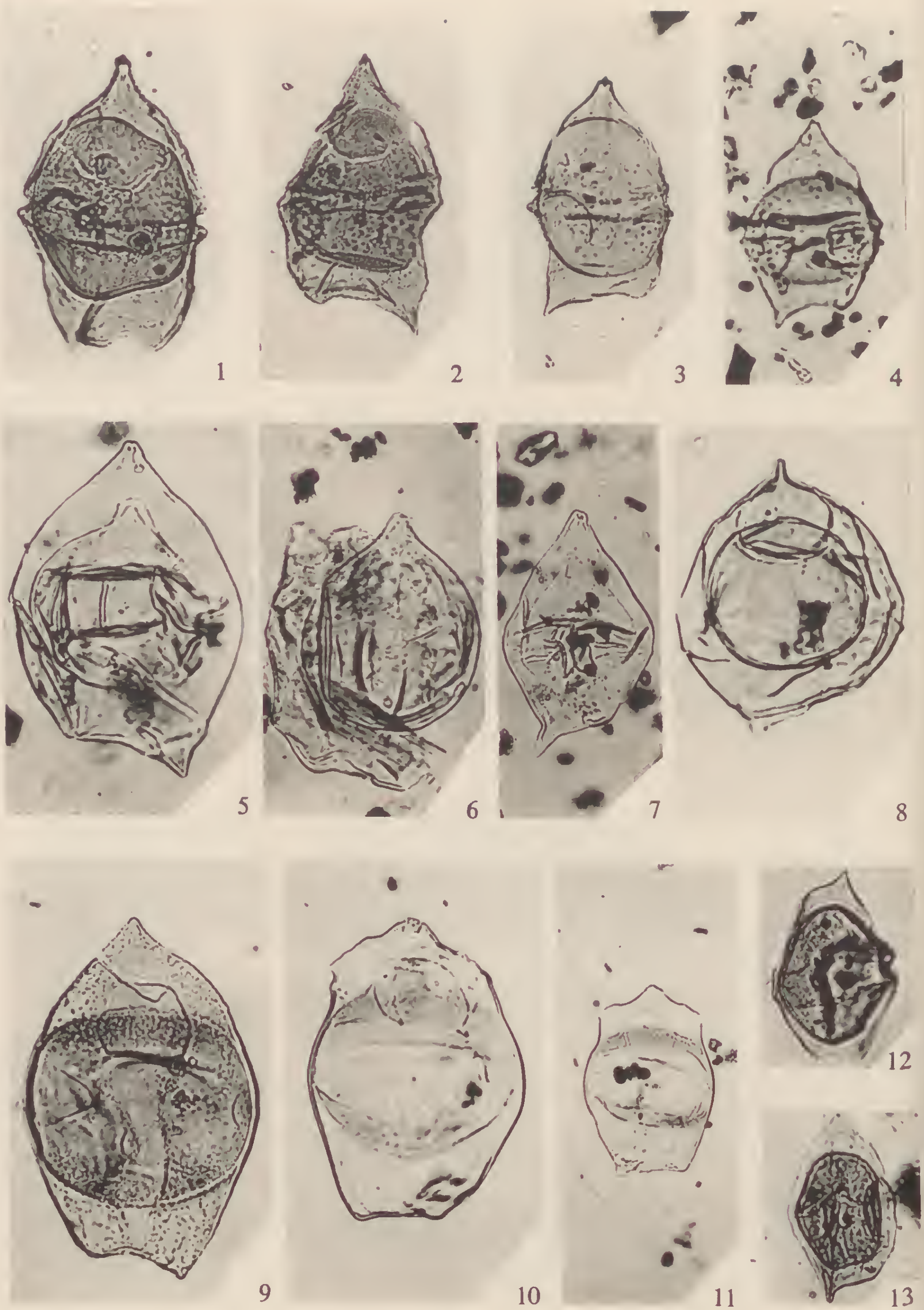
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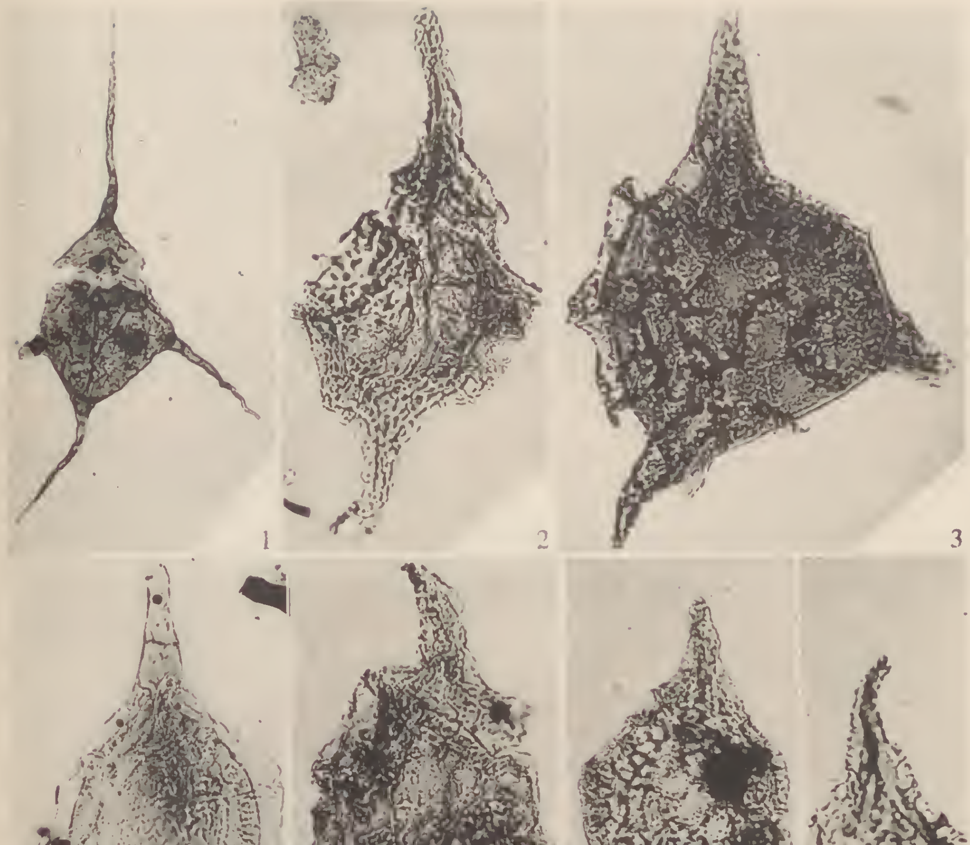
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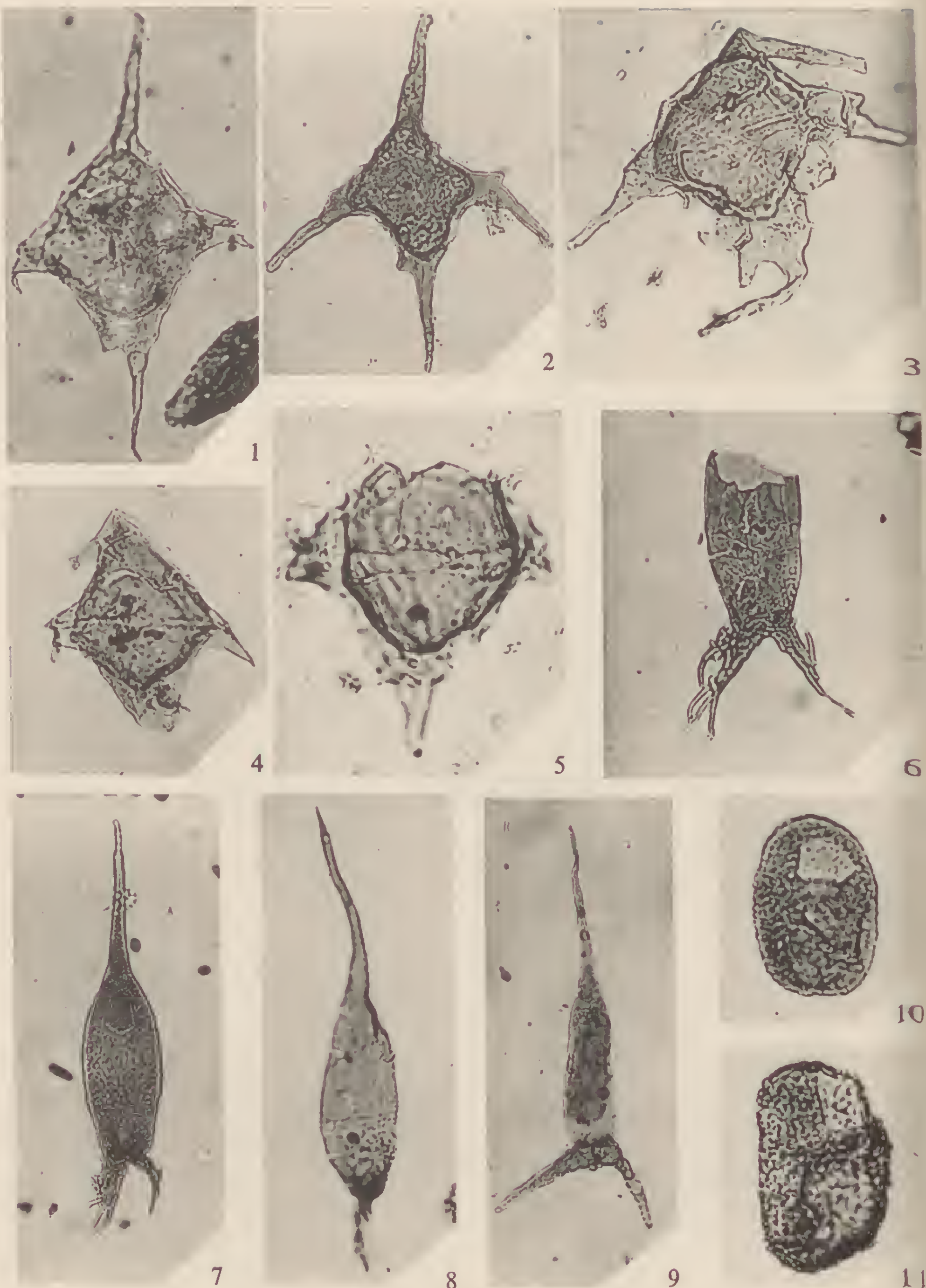
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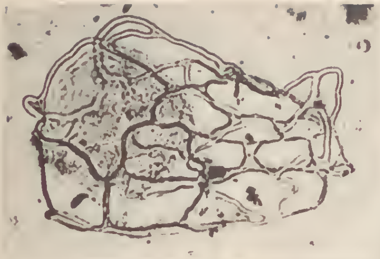
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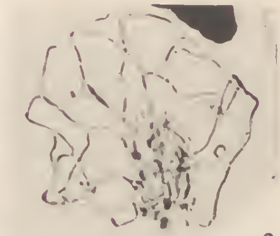
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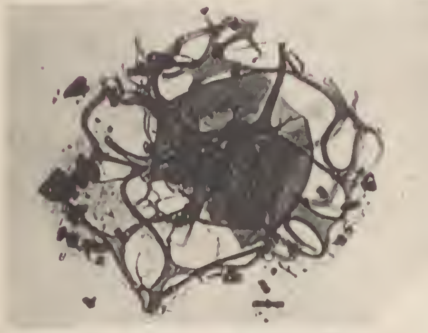
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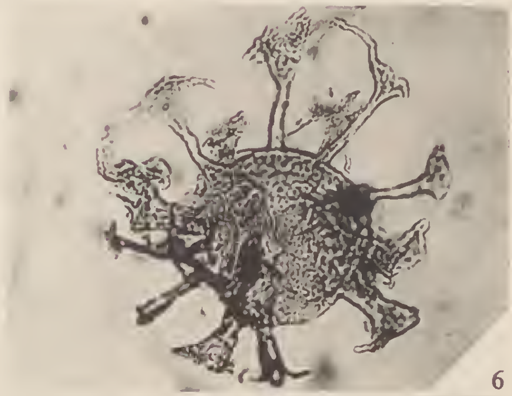
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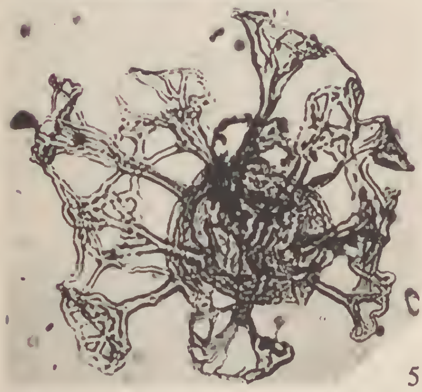
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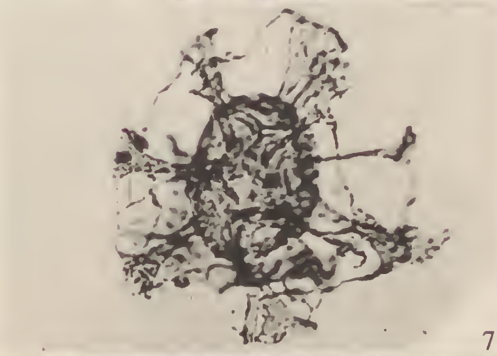
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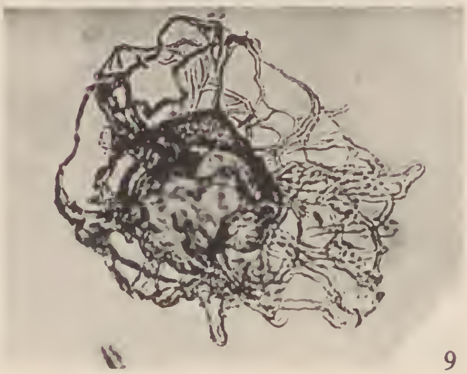
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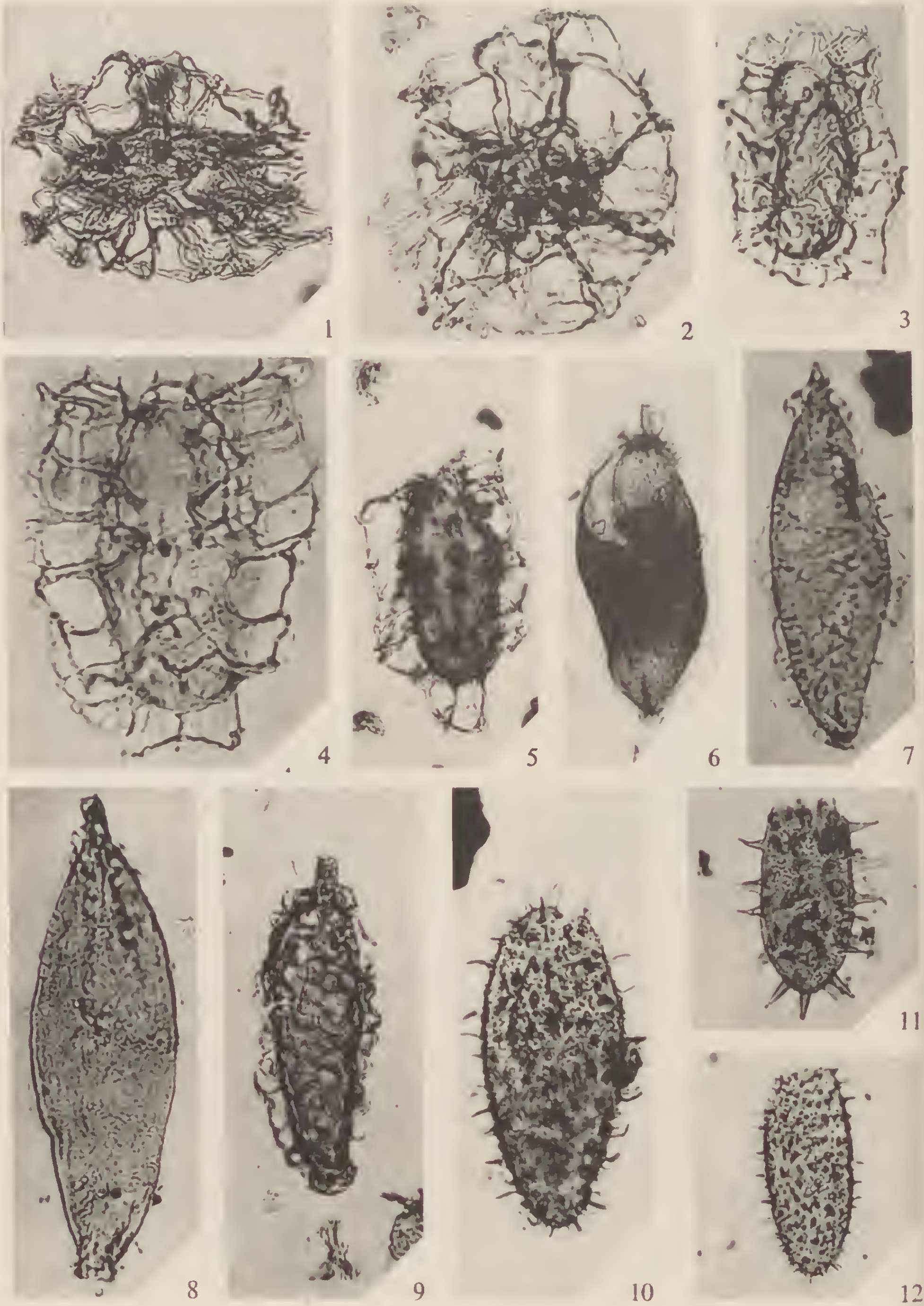
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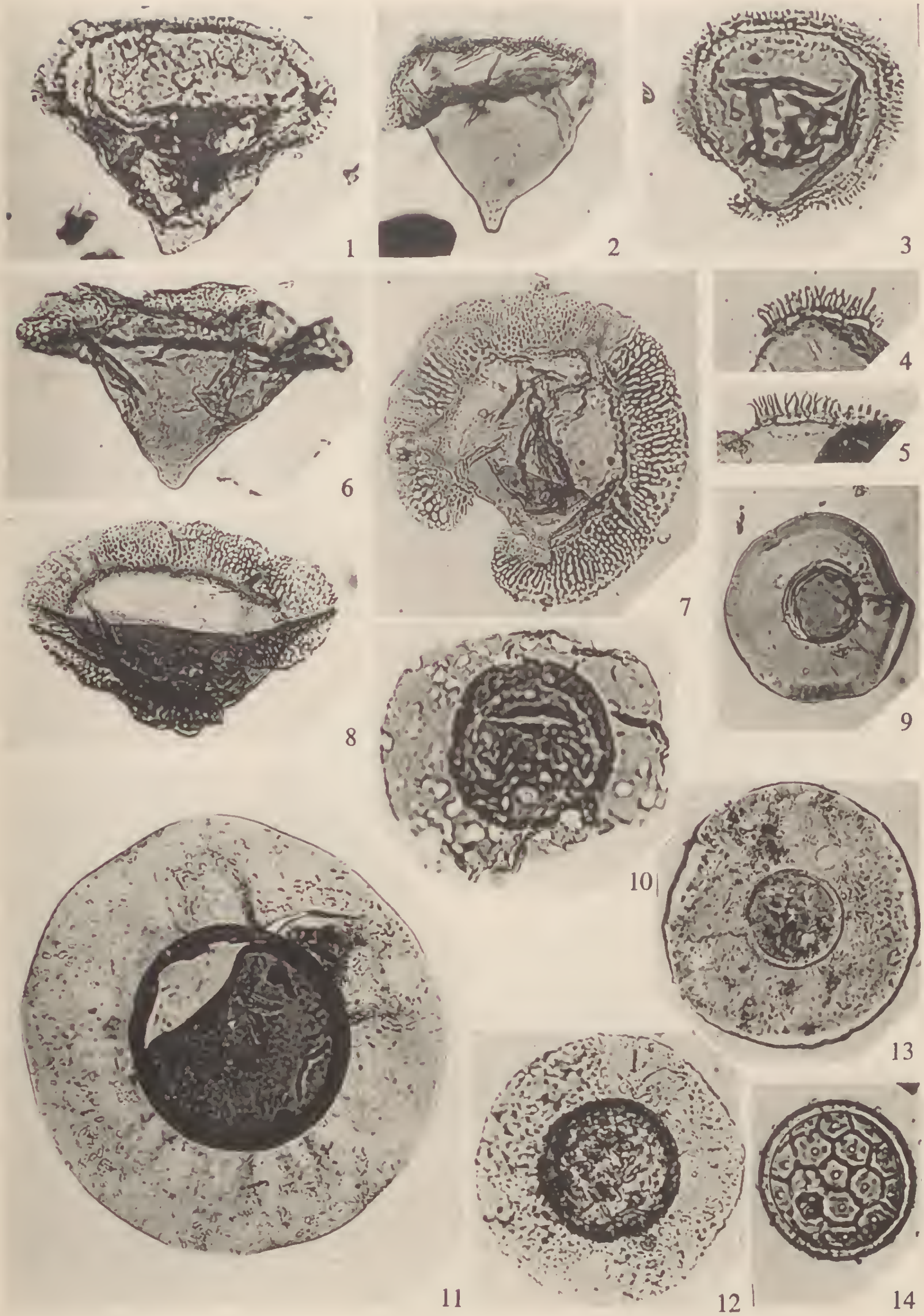
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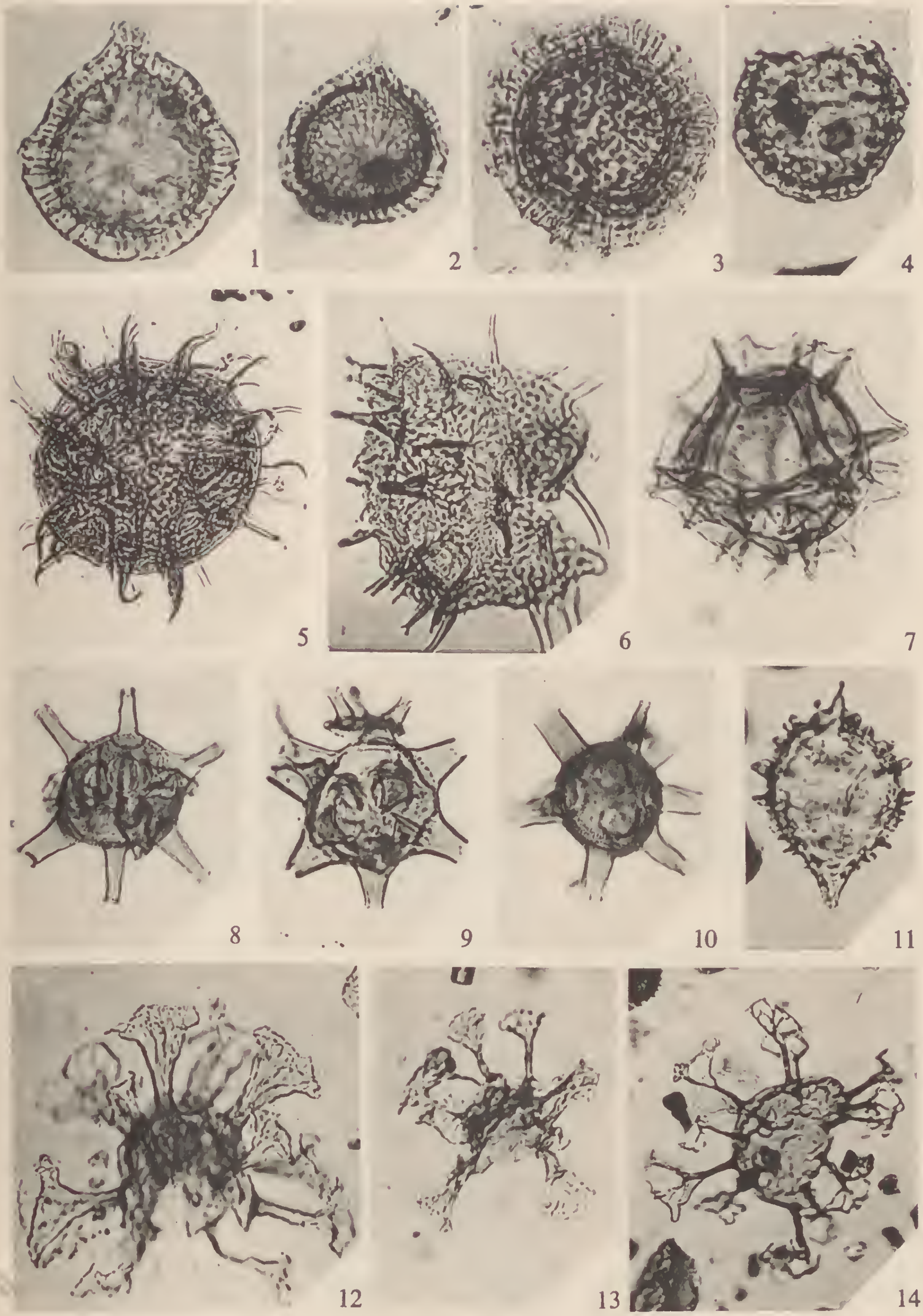
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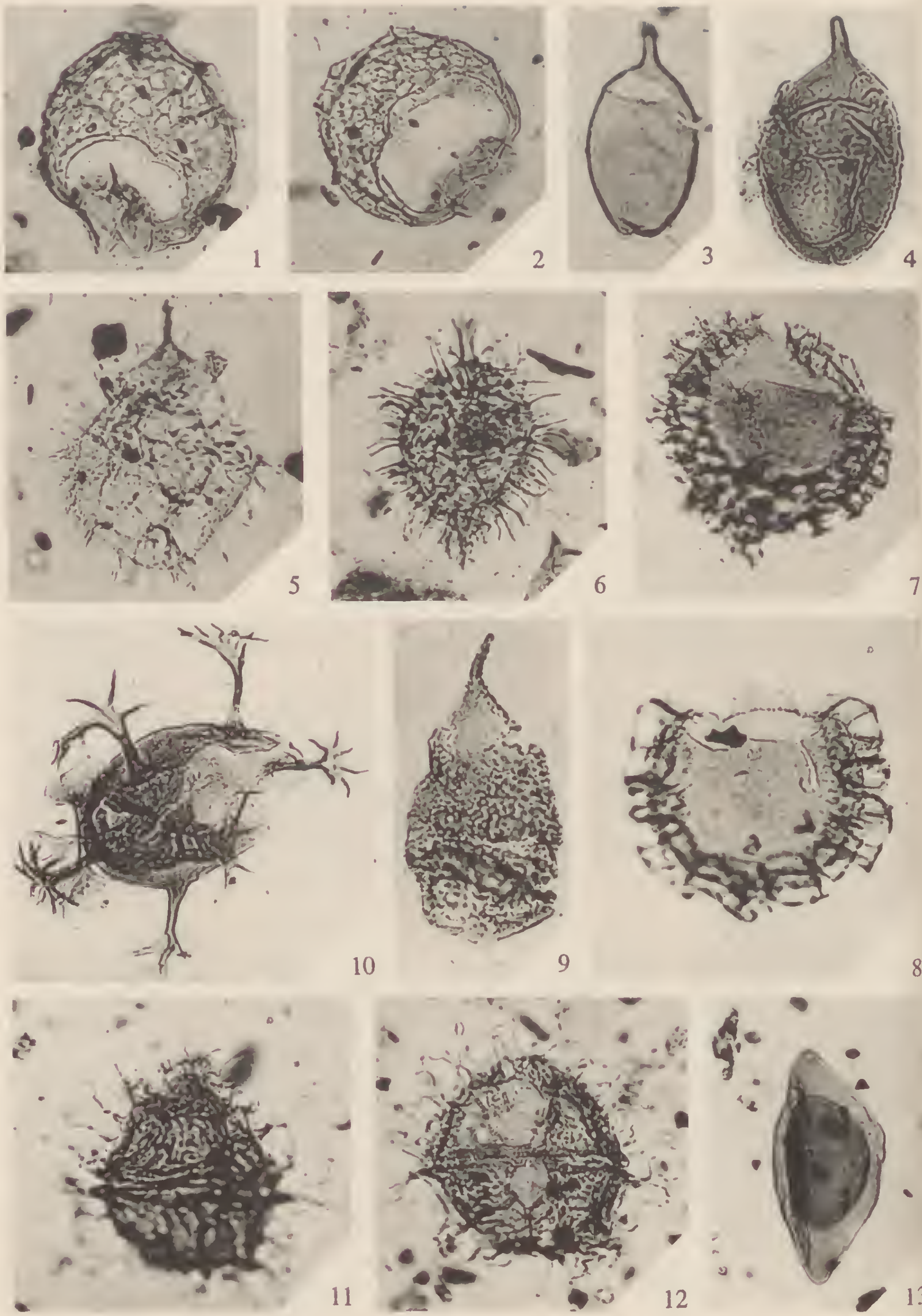

Appendix 1

These forms are referable to the new genus *Scriniodinium* Klement (*Neues Jb. Palaontol*, M.L. 1957, 9; 408-410), which was published after this paper went to press. The new genus is in accordance with the observations of the present authors that "These four species, in having flattened shells with thin margins, central capsules and conspicuous pylomes are distinct from such true fossil *Gymnodinia* as *Gymnodinium cretaceum* Defl., *G. heterocostatum* Defl., and *G. nelsonense* Cookson. It seems probable, therefore, that eventually they will be removed from the genus *Gymnodinium*".

Appendix 2

During the publication of this paper, a number of excellent specimens of *Cannosphaeropsis fenestrata* Deflandre and Cookson have been recovered from Wapet's Rough Range South Bore No. 1. As a result, it is now clear that the specimens herein provisionally referred to *C. fenestrata* represent a distinct species. This new species will be described in a subsequent paper.

Appendix 3

During the publication of this paper. advice has been received that, in the stratigraphy of Western Australia, the Dingo Siltstone is now referred to as the Dingo Claystone.

3

FISH OTOLITHS FROM THE TERTIARY STRATA OF VICTORIA, AUSTRALIA

By F. C. Stinton*

[Communicated by Edmund D. Gill, 11 July 1957]

Abstract

Palaeontological studies af the Tertiary strata of Victoria have dealt only briefly with teleostean otoliths which are not uncommon at some horizons. The present paper seeks to rectify this omission by describing otoliths representing 20 species of Teleosts, of which 16 were previously undescribed.

Physical and climatic conditions obtaining during Tertiary times are discussed in relation to the teleostean genera represented.

Introduction

Although otoliths of teleostean fishes are not uncommon in the Tertiary strata of Australia, the subject has been largely neglected. To the present, only 4 species have been described, 3 by G. A. Frost in 1925, from Balcombe Bay, Victoria, and one by the present author in 1952, from the Pliocene of South Australia.

Recently, Edmund D. Gill, Curator of Fossils, National Museum of Victoria, kindly submitted 72 otoliths to the author for examination, and this series has been further augmented by 22 specimens collected by D. Curry during a visit to Australia in 1953. This series comprises 20 species to be described hereafter, 16 of which are new to the Australian Tertiary fish fauna.

All of the specimens are sagitta otoliths, no other type of otolith having so far been reported in Australia.

For details of the morphology of a sagitta otolith, reference should be made to a paper by the author (1952).

All the figured otoliths bear the registration numbers of the National Museum of Victoria, where the collections are housed.

Systematic Description of Species

Sub-class Actinopterygii

Superorder Telelostei

Order Isospondyli

Family Elopsidae

Genus **Megalops** Lacepède, 1803

1803 Lacepède, *Hist. Nat. Poiss.*, *5*; 269.

Megalops lissa n.sp.

(Pl. XIII, figs. 8, 23)

Types: Holotype P 16938; paratype P 16949.

Dimensions: Fig. 8—Length, 3·63 mm., width 2·22 mm.; Fig. 23—Length, 2·03 mm., width 1·10 mm.

* Bournemouth, Hants, England.

Description: A biconvex, left sagitta otolith. Posterior and ventral rims rounded, dorsal rim rounded and slightly scalloped anteriorly, anterior rim concave. Outer face showing feeble ribbing on the antero-dorsal part of the otolith. Inner face smooth with a narrow, central sulcus which opens widely on the anterior rim and does not reach the posterior rim. Ostium narrow and shallow with a concave lower rim; cauda down-curving, long, and narrower than the ostium from which it is delineated by a slight lower angle. Marked rostrum, slight antirostrum and excisura. No colliculi. A shallow groove above the crista superior.

Fig. 23 represents a juvenile example and is relatively narrower than the adult form. It also shows some scalloping of the posterior rim, a feature not shown in the adult specimens.

This otolith shows a close resemblance to those of the living *Megalops cyprinoides* Broussonet in the character of its sulcus, but differs in its rounded outline and more markedly concave anterior rim. The specific name refers to the general smoothness of the otolith.

Occurrence and localities: 2 specimens, P 16938-9, Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection. One specimen P 16940, *Limopsis* Beds (Oligocene), Bird Rock, Torquay, Victoria, D. Curry collection.

Family Pterothrissidae

Genus **Pterothrissus** Hilgendorf, 1877

1877 Hilgendorf, *Leopoldina,* 13 (15-16); 127.

Pterothrissus pervetustus n.sp.

(Pl. XIII, fig. 21)

Type: Holotype P 16941.

Dimensions: Length 7·68 mm.; width 4·42 mm.

Description: An oval, biconvex, right sagitta otolith, tapering posteriorly. Anterior, posterior and ventral rims rounded; dorsal rim almost straight. Outer face ornamented with small ridges and tuberosities, the latter concentrated towards the centre of the otolith. Inner face smooth. Sulcus diagonal, opening on antero-dorsal rim and not reaching posterior rim. Ostium rectangular; cauda straight, narrow and rounded at its extremity. No rostrum, antirostrum or colliculi present. Excisura present.

This otolith is typical of the genus *Pterothrissus,* resembling those of the living form *Pterothrissus belloci* Cadenat. It is also similar to the common English Eocene form *Pterothrissus umbonatus* (Koken), but the Australian form differs in its posterior tapering while the European form is more rectangular in outline. The specific name indicates an ancestral form of this extant genus.

Occurrence and locality: 3 specimens P 16941-3, Janjukian (Oligocene), Spring Creek, Victoria, Dennant collection.

Frost (*Trans. N.Z. Inst., 55*; 613, 1924) has described a similar form from the Miocene of New Zealand as co-specific with the European *Pterothrissus umbonatus* (Koken), but it is probable that this specimen is synonymous with the Australian species.

Order Apodes

Family Congridae

Genus **Uroconger** Kaup, 1856

1856 Kaup, *Cat. Apod. Fish. Br. Mus.,* 110.

Uroconger rectus (Frost)

(Pl. XIII, figs. 3, 12)

1928 *Congeris rectus* Frost G.A., *Trans. N.Z. Inst.*, 59; 93.

Types: Hypotypes P 16944-5.

Dimensions: Fig. 12—Length 3·90 mm., width 2·05 mm. Fig. 3—Length 2·95 mm., width 1·86 mm.

Description: Right, biconvex, sagitta otoliths, pointed posteriorly and anteriorly. Dorsal rim flattened, posterior and anterior rims oblique, ventral rim rounded. Outer and inner faces smooth. Sulcus opening on anterior rim and extending diagonally half way across the face of the otolith. Very short, triangular ostium and short, narrow cauda. No colliculi.

These otoliths are identified with the form described by Frost (loc. cit.) from the Lower Miocene or Oligocene of Otiake and Clifden, New Zealand. The character of the sulcus and general outline are comparable with otoliths from the living species *Uroconger lepturus* Richardson, and the fossil form is referred to this genus.

Occurrence and localities: 2 specimens P 16944-5, Balcombian (Miocene) Beds H-K, Balcombe Bay, Victoria, D. Curry collection. One specimen P 16950, Kalimnan (Lower Pliocene), McDonald's Bank, Muddy Creek, Victoria, Dennant collection.

Genus **Astroconger** Jordan and Hubbs, 1925

1925 Jordan and Hubbs, *Mem. Carn. Mus., 10*; 192.

Astroconger rostratus n.sp.

(Pl. XIII, fig. 16)

Type: Holotype P 16946.

Dimensions: Length 6·00 mm., width 2·37 mm.

Description: An elongate, narrow, biconvex, left sagitta otolith, beaked posteriorly, pointed anteriorly. Dorsal and ventral rims slightly rounded. Outer and inner faces smooth. Narrow sulcus running nearly parallel to the ventral rim and extending across three quarters of the inner face of the otolith. It is divided into ostium and cauda by a slight widening of the anterior third of the sulcus. A shallow depression above the crista superior. No colliculi.

This otolith generally resembles those of the living form *Astroconger myriaster* Brevoort, but differs in the beaked posterior form of the fossil, from which the specific name is derived.

Occurrence and locality: One specimen, *Glycymeris* Beds (Oligocene), Bird Rock, Torquay, Victoria, D. Curry collection.

Family Muraenesocidae

Genus **Muraenesox** McClelland, 1843

1843 McClelland, *Calcutta Journ. Nat. Hist., 4*; 408.

Muraenesox obrutus n.sp.

(Pl. XIII, fig. 2)

Type: Holotype P 16947.

Dimensions: Length 4·36 mm., width 2·54 mm.

Description: A biconvex, left sagitta otolith, pointed posteriorly. Dorsal rim straight, anterior rim oblique, ventral rim rounded. Smooth outer and inner faces. Slight diagonal sulcus opening on anterior rim and not reaching posterior rim. Very

short, triangular ostium and longer, narrower cauda. No rostrum, antirostrum or excisura.

Although somewhat eroded, the sulcus of this otolith is typical of the genus *Muraenesox*, resembling otoliths of the living *Muraenesox talabon* Cantor, to which genus this specimen is assigned. The specific name means "buried".

Occurrence and locality: One specimen, Balcombian (Miocene), Clifton Bank, Muddy Creek, near Hamilton, Victoria, Dennant collection.

Family Heterenchelyidae

Genus **Heterenchelys** Regan, 1912

1912 Regan, T., *Ann. Mag. Nat. Hist.*, (8), *10*; 377-387.

Heterenchelys regularis n.sp.

(Pl. XIII, fig. 20)

Type: Holotype P 16948.

Dimensions: Length 9·04 mm.; width, 5·88 mm.

Description: A biconvex, left sagitta otolith, roughly rhomboidal in outline. Pointed anteriorly and posteriorly. Dorsal and ventral rim rounded. Outer and inner faces smooth. Sulcus somewhat diagonal, consisting of a wide, short, triangular ostium opening on the anterior rim and a short, straight cauda. Sulcus filled with a colliculum. No rostrum, antirostrum or excisura. A shallow, rectangular depression above the crista superior.

This otolith compares closely with those of the living *Heterenchelys macrurus* Regan, but differs in its more rhomboidal outline.

Occurrence and localities: P 16948 Balcombian (Miocene), Gellibrand Clay, near Princetown, Victoria; P 16949 Balcombian (Miocene), Shelford, Victoria; Dennant collection.

Order Anacanthini

Family Merlucciidae

Genus **Merluccius** Rafinesque, 1810

1810 Rafinesque, *Carratt. di Alc. Nuovi Gen., etc.*, 25.

Merluccius fimbriatus n.sp.

(Pl. XIII, fig. 27)

Type: Holotype P 16951.

Dimensions: Length 14·78 mm., width 5·25 mm.

Description: A thin, right sagitta otolith, somewhat abraded. Dorsal rim rather irregularly denticulated; ventral rim rounded and fimbriated; vertical, fimbriated anterior rim. Pointed posteriorly. Outer face ornamented with parallel ribbing from the median line to all the rims with a prominent diagonal ridge from the antero-dorsal corner to the centre of the otolith. Smooth, inner face with an enclosed sulcus divided nearly equally into ostium and cauda by a marked lower notch. Ostium and cauda partially filled with colliculi.

This is a typical merlucciid otolith comparing well with those of the living *Merluccius vulgaris* Fleming, but differing in its outline.

Occurrence and locality: One specimen, Balcombian (Miocene), Balcombe Bay, Victoria, R. W. T. Wilkins collection.

Family Gadidae

Genus **Gadus** Linnaeus, 1758

1758 Linnaeus (Artedi), *Syst. Nat.*, ed. X; 251.

Gadus refertus n.sp.

(Pl. XIII, figs. 7, 15)

Types: Holotype P 16952; paratype P 16953.

Dimensions: Fig. 7—Length 4·26 mm., width 2·32 mm. Fig 15—Length 5·71 mm., width 4·25 mm.

Description: A left, biconvex, sagitta otolith prominently pointed posteriorly. Dorsal rim rounded, with a projecting knob at its junction with the oblique anterior rim. Ventral rim rounded. Outer face showing several large, indistinct tuberculations. Smooth inner face. Enclosed sulcus which is divided near its centre into ostium and cauda by a lower notch and diagonal line. Ostium and cauda spherical and filled with colliculi to the level of the surrounding face of the otolith.

Fig. 15 is an eroded left specimen in which the sulcus closely resembles the type found in ophidioid otoliths.

The general outline of this otolith, together with the characteristic sulcus, place it in the genus *Gadus*, comparing well with otoliths of the living *Gadus luscus* Linnaeus. The specific name refers to the filled-in sulcus.

Occurrence and localities: One specimen P 16952 Janjukian (Oligocene), Spring Creek, Victoria, Dennant collection. One specimen P 16953 *Glycymeris* Beds (Oligocene), Bird Rock, Torquay, Victoria, D. Curry collection.

Family Bregmacerotidae

Genus **Bregmaceros** (Cantor) Thompson, 1840

1840 (Cantor) Thompson, in *Charlesworth's Mag. Nat. Hist.*, 184.

Bregmaceros minutus n.sp.

(Pl. XIII, fig. 22)

Type: Holotype P 16954.

Dimensions: Length 0·98 mm., width 1·09 mm.

Description: A minute, left sagitta otolith. High dorsal rim, rounded posterior and anterior rims, the latter with a rounded upper notch; straight ventral rim. Smooth, convex outer face. Smooth, flat inner face. Sulcus enclosed, consisting of a median, slightly curved, narrow groove with a slight central constriction. A slight, triangular depression above the crista superior. No colliculi.

This otolith shows a marked resemblance to those of the living form *Bregmaceros atripinnis* Day, but differs in the notch on the antero-dorsal rim.

Occurrence and locality: 6 specimens, Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, P 16954 and P 17307-11, D. Curry collection.

Famliy Coryphaenoididae

Genus **Coelorhynchus** Giorna, 1803

1803 Giorna, *Mem. Ac. Sci. Turin*, 16; 178. Pl. I, figs. 3, 4.

Coelorhynchus elevatus Stinton

(Pl. XIII, figs. 9, 13, 17)

1924 *Otolithus (Macrurus) toulai* Frost G. A., *Trans. N.Z. Inst.*, 55; 608.
non Schubert R. J., *Jb. geol. Reichsanst.*, 55; 620, 1905.
1956 *Coelorhynchus elevatus* Stinton F. C., *Trans. Roy. Soc. N.Z.*, 84, pt. 3. Pl. XXXII, fig. 13.

Types: Hypotypes P 16955-57.

Dimensions: Fig. 9—Length 6·04 mm., width 4·13 mm. Fig. 13—Length 4·60 mm., width 3·35 mm. Fig. 17—Length 6·36 mm., width 4·00 mm.

Description: Biconvex, left sagitta otoliths, pointed posteriorly and anteriorly. High, denticulated dorsal rim, nearly vertical; denticulated posterior rim; finely denticulated, rounded ventral rim. Outer face strongly ribbed on all the rims. Smooth inner face with a narrow, median, shallow sulcus which almost touches the posterior and anterior ends of the otolith. Ostium sphaeroidal and shorter than the long, wider cauda which is separated by a constriction of the superior and inferior cristae. No colliculi.

This form, described by Frost (1924, loc. cit.) as *Macrurus toulai* Schubert, is obviously referable to the genus *Coelorhynchus* when compared with otoliths from the living *Coelorhynchus fasciatus* Gnthr. Examination of the indistinct figures of Schubert's species *Macrurus toulai* shows a relatively shorter otolith with a wider sulcus in keeping with a typical otolith of the genus *Macrurus* sensu stricto.

Occurrence and localities: P 16955 Balcombian (Miocene), Balcombe Bay, Victoria, R. W. T. Wilkins collection; P 16956 Balcombian (Miocene), Shelford, Victoria, Dennant collection; P 16957 Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection.

Order BERYCOMORPHI

Family MONOCENTRIDAE

Genus **Monocentris** Bloch and Schneider, 1801

1801 Bloch and Schneider, *Syst. Ichth.*, 100.

Monocentris sphaeroides n.sp.

(Pl. XIII, fig. 25)

Type: Holotype P 16958.

Dimensions: Length 7·46 mm., width 7·77 mm.

Description: A deep, oval, left sagitta otolith. All rims regularly rounded with a faint scalloping on the dorsal rim. Outer face convex, ornamented on the antero-dorsal rim with short, parallel ribs. Flat inner face. Sulcus opening narrowly on the anterior rim, crossing the middle of the otolith and not reaching the posterior rim. Wide, shallow, down-turned ostium; up-turned, oval, shallow cauda. Ostium and cauda sharply delineated by a prominent notch on the crista inferior. The concave crista superior has a wide, shallow depression above it. No rostrum, antirostrum, excisura or colliculi.

This otolith compares closely with those of the living species *Monocentris japonicus* Houttuyn, but differs in its more oval outline. *Monocentris lemoinei* Priem, described by Frost (1924, loc. cit.) from Balcombe Bay, Victoria, is a relatively more rounded otolith.

Occurrence and locality: One specimen, Pliocene, Aldinga, South Australia, Dennant collection

Genus **Cleidopus** de Vis, 1883

1882 de Vis, *Proc. Linn. Soc. N.S.W.*, 7; 367.

Cleidopus cavernosus n.sp.

(Pl. XIII, fig. 26)

Type: Holotype P 16959.

Dimensions: Length 5·23 mm., width 6·00 mm.

Description: A right, sagitta otolith. Dorsal rim straight and slightly sloping upwards posteriorly. Produced slightly at junction of dorsal and posterior rims. Anterior and posterior rims nearly vertical and slightly rounded. Ventral rim nearly horizontal. Convex outer face ornamented on the upper half with 3 wide, indistinct, radial tuberculations. Inner face nearly flat. A wide, excavated, median sulcus opening narrowly on the anterior rim and nearly reaching the posterior rim. Ostium wide, shallow, circular; cauda short, wide, spherical, sharply delineated by prominent notches on the upper and lower rims of the sulcus. No rostrum, antirostrum, excisura or colliculi. A very narrow, shallowly depressed area above the sulcus and a wide area below it.

The outline and sulcus of this otolith compare closely with those of the living *Cleidopus gloria-maris* de Vis, but it differs in the more rounded, straighter and wider cauda. The otolith of the living form is markedly more produced in the postero-dorsal area and possibly the fossil form is similarly more produced but it has suffered somewhat from attrition. The Recent otoliths were obtained from two extant examples from Surfers' Paradise, Queensland, kindly supplied to the author by Mrs. P. Doran. The specific name refers to the hollowed-out appearance of the sulcus.

Occurrence and locality: One specimen, *Limopsis* Beds (Oligocene), Torquay, Victoria, D. Curry collection.

Family TRACHICHTHYIDAE

Genus **Trachichthodes** Gilchrist, 1903

1903 Gilchrist, *Mar. Invest. S. Afr., 2*; 203.

Trachichthodes salebrosus n.sp.

(Pl. XIII, figs. 19, 24, 28)

Types: Holotype P 16960, paratypes P 16961-2.

Dimensions: Fig. 19—Length, 2·53 mm., width 2·08 mm. Fig. 24—Length 7·46 mm., width 6·97 mm. Fig. 28—Length 6·33 mm., width 5·36 mm.

Description: A hexagonal, right sagitta otolith. Dorsal and ventral rims straight. Obtuse-angled anterior and posterior rims. Outer face ridged centrally and with short, radial ribs all round the rims, probably producing scalloping in unabraded specimens. The central ridge slopes towards the dorsal and ventral rims. Prominent ribbing on the edge of the outer face is shown in paratype P 16961. Smooth, slightly convex inner face. Central sulcus opening narrowly on the anterior rim and almost reaching the posterior rim. Ostium diagonal, oval, wide shallow; cauda straight, narrow, rather up-turned and differentiated from ostium by a prominent notch on the crista inferior. No rostrum, antirostrum, excisura or colliculi. A shallow depression above the crista superior.

Paratype P 16962 represents a juvenile specimen showing marked scalloping of the rims. It is less hexagonal in outline and is more rounded generally.

This otolith compares closely with those of the living Australian form *Trachichthodes affinis* Guenther, differing only in the ribbing of rims and in being relatively somewhat higher. The specific name refers to the rugged appearance of the outer face.

Occurrence and localities: P 16960 Balcombian (Miocene), Balcombe Bay, Victoria, R. W. T. Wilkins collection; P 16961 Balcombian (Miocene), Shelford, Victoria; P 17312 Janjukian (Oligocene) or (Miocene), Maude, Victoria; P 17313 Balcombian (Miocene), Curlewis, Victoria; P 17314 Balcombian (Miocene), Clifton

Bank, Muddy Creek, near Hamilton, Victoria, Dennant collection; P 16962 Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection.

Order PERCOMORPHI

Sub-order PERCOIDEA

Genus **"Percidarum"**

"Percidarum" clivosum n.sp.

(Pl. XIII, fig. 18)

Type: Holotype P 16963.

Dimensions: Length 2·73 mm., width 1·71 mm.

Description: A thin, right sagitta otolith, pointed anteriorly. Dorsal rim rising posteriorly and denticulated; denticulated, rounded posterior and ventral rims. Concave outer face with small tuberculations all round the edges. Inner face smooth centrally but scalloped towards the rims. A straight, horizontal sulcus opening on the anterior rim and not reaching the posterior rim. A short, shallow ostium and a long, narrower cauda, delineated by a lower and rounded upper angles. Rostrum, slight antirostrum and excisura present. No colliculi. A shallow depression above the crista superior, accentuating it.

Comparison of this otolith with those of the living types at present represented in the author's collection does not show sufficient affinities for its accurate generic determination. In character it is typically percoid and the form of the sulcus compares somewhat with that of otoliths from the living *Grammistes sexlineatus* Thunberg, but it is distinct in general outline. The specific name refers to the hillocky appearance of the ornamentation on the outer face.

Occurrence and locality: One otolith, Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection.

Family LACTARIIDAE

Genus **Lactarius** Cuvier et Valenciennes, 1833

1833 Cuvier et Valenciennes, *Hist. Nat. Poiss., 9*; 237.

Lactarius tumulatus n.sp.

(Pl. XIII, fig. 5)

Type: Holotype P 16964.

Dimensions: Length 3·48 mm., width 2·51 mm.

Description: A biconvex, left sagitta otolith. Horizontal dorsal rim, slightly scalloped; vertical posterior rim and rounded anterior rim, both denticulated; oblique anterior rim. Outer face feebly ornamented with irregular tuberculations. Inner face smooth and almost flat. A median sulcus opening on the anterior rim and not quite reaching the posterior rim. Ostium somewhat slanting downwards, oval and relatively wide; cauda straight, narrow, fairly long and slightly downcurved at its extremity. A slight rostrum but no antirostrum or excisura. No colliculi. A slight depression above the crista superior.

This otolith is very similar to those of the living *Lactarius lactarius* Bloch and Schneider, both in its general shape and the character of the sulcus, but differs in the denticulated rims and more flattened dorsal rim. The specific name means "buried".

Occurrence and locality: Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection.

Family Sillaginidae

Genus **Sillago** Cuvier, 1817

1817 Cuvier, *Reg. Anim.*, *2*; 258.

Sillago pliocaenica Stinton

(Pl. XIII, fig. 4)

1952 Stinton, F. C., *Trans. Roy. Soc. S. Austr.*, *76*; 66.

Type: Hypotype P 16965.

Dimensions: Length 5·77 mm., width 4·68 mm.

Description: A left, sagitta otolith. Dorsal rim produced to a small, central point and very feebly denticulated. Rounded posterior, ventral and anterior rims. Concave outer face, thickened centrally; feeble radial ridges on the rims, otherwise smooth. Smooth, sharply convex inner face. Sulcus just touching anterior rim, running closely parallel with the dorsal rim, almost to the posterior rim. A short, oval ostium and a fairly wide, undulating cauda separated by a very thin line which curves slightly in its centre. Sulcus entirely filled with colliculi. No rostrum, anti-rostrum or excisura.

This otolith is the commonest form represented in the Tertiary formations of Victoria and also in the Pliocene of South Australia.

Occurrence and localities: P 16965-79, 15 specimens, Cheltenhamian (Upper Miocene), Cheltenham (= Beaumaris), Victoria; P 16980 Balcombian (Miocene), Shelford, Victoria; P 16981-86, 6 specimens, Janjukian (Oligocene), Spring Creek, Victoria; P 16987-9, 3 specimens, Balcombian (Miocene), Clifton Bank, Muddy Creek, near Hamilton, Victoria; P 16990-1, 2 specimens, Kalimnan (Lower Pliocene), MacDonald's Bank, Muddy Creek, near Hamilton, Victoria; P 16992-17000 and 17154-8, 14 specimens, Janjukian (Oligocene) or (Miocene), Maude, Victoria; P 17159-60, 2 specimens, Miocene, Mitchell River, Victoria; Dennant collection.

Sub-order Ophidioidea

Family Carapidae

Genus **Jordanicus** Gilbert, 1905

1905 Gilbert, *Bull. U.S. Fish. Comm.*, *23* (1903); pt. 2, 656.

Jordanicus exiguus Stinton

1956 *Jordanicus exiguus* Stinton F. C., *Trans. Roy. Soc. N.Z.*, *84*; pt. 3. Pl. XXXII, fig. 9.

Types: Hypotypes P 17161-2.

Dimensions: Fig. 6—Length 3·56 mm., width 2·18 mm. Fig. 11—Length 4·57 mm., width 2·04 mm.

Description: Triangular, biconvex, left sagitta otoliths, pointed anteriorly and posteriorly. Domed, dorsal rim, feebly scalloped; slightly rounded ventral rim. Outer face ornamented with radial tuberculations on the dorsal rim, otherwise smooth. Smooth inner face. Sulcus completely enclosed, triangular, undivided and completely filled with a colliculum.

This otolith compares well with otoliths from the living *Jordanicus gracilis* Bleeker, but is relatively longer and less biconvex than the living form.

Occurrence and locality: P 17161, Balcombian (Miocene), Curlewis, Victoria; P 17162, (Miocene), Mitchell River, Victoria; Dennant collection.

Family Ophidiidae

Genus **Ophidion** Linnaeus, 1758

1758 Linnaeus, *Syst. Nat.*, ed. X, 242; 259.

The name *Ophidium* is found in Linnaeus's *Systema Naturae* (12 ed.) and is generally used but *Ophidion* is the genus officially listed in the Rules of Zoological Nomenclature (op. 92).

Ophidion granosum n.sp.

(Pl. XIII, fig. 14)

Type: Holotype P 17411.

Dimensions: Length 2·45 mm., width 1·40 mm.

Description: A biconvex, left sagitta otolith, pointed posteriorly. Dorsal rim straight, anterior and ventral rims rounded, posterior rim very short and oblique. Outer face ornamented with indistinct tuberculations which are more distinct on the antero-ventral rims. Inner face smooth and almost flat. Sulcus entirely enclosed. Ostium long and oval, cauda very small, circular and differentiated from the ostium by a prominent notch on the lower rim. Sulcus completely filled with colliculi.

This otolith is typical of the genus *Ophidion* in its outline and the character of the sulcus. The specific name refers to the resemblance of this otolith to a small seed or pip.

Occurrence and locality: Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection.

Order Scleroparei

Family Platycephalidae

Genus **Platycephalus** Bloch, 1795

1795 Bloch, *Ichthyol.*, *12*; 90.

Platycephalus petilus n.sp.

(Pl. XIII, fig. 1)

Type: Holotype P 17412.

Dimensions: Length 6·37 mm., width 2·46 mm.

Description: A rather waterworn, thin, narrow, elongate right sagitta otolith, pointed anteriorly and posteriorly. Dorsal rim rounded and feebly scalloped, ventral rim rounded and scalloped, at its posterior end. Outer face concave with radial ribbing to the dorsal rim, the ribbing being finer at the posterior end. Inner face convex with faint ribbing on the dorsal half. A narrow, somewhat deep sulcus opening narrowly on the anterior rim and extending two-thirds of the way across the otolith. Ostium slightly wider than cauda and equal in length to it. Cauda slightly down-curved at its pointed extremity. A slight rostrum but no antirostrum or excisura. No colliculi.

This otolith compares closely with those of the living *Platycephalus insidiator* Forkskål, but it is relatively wider than the living form. The specific name refers to the thin, narrow form of the otolith.

Occurrence and locality: Miocene, Mitchell River, Victoria, Dennant collection.

Order Heterosomata

Family Pleuronectidae

Genus **Pleuronectes** (Artedi) Linnaeus, 1758

1758 (Artedi) Linnaeus, *Syst. Nat.*, ed. *X*, 268.

Pleuronectes vulsus n.sp.

(Pl. XIII, fig. 10)

Type: Holotype P 17413.

Dimensions: Length 3·04 mm. (incomplete), width 1·83 mm.

Description: An incomplete, oval, biconvex right sagitta otolith, the anterior end missing. Pointed posteriorly. Dorsal and ventral rims rounded. Outer and inner faces smooth. Sulcus excavated and possibly enclosed but anterior characters lost. Ostium apparently a shallow, oval depression; cauda a much smaller, circular depression, somewhat upturned.

The character of the sulcus suggests a close affinity to the *Pleuronectidae* in which genus this otolith is tentatively placed. The specific name refers to the smoothness of the otolith.

Occurrence and locality: Balcombian (Miocene), Beds H-K, Balcombe Bay, Victoria, D. Curry collection.

Conclusions

The otolith assemblage suggests a rather deep-water facies, possibly deposited on the edge of the continental shelf, as evidenced by the presence of the genera *Pterothrissus, Bregmaceros, Ophidion* and the pelagic *Megalops*. However, the occurrence of *Platycephalus* and *Lactarius* suggests more littoral conditions and, as this peculiar admixture of genera occurs throughout the Eocene of Europe, as in the Tertiary of Australia, it is possible that the deep-sea forms of the present day were able to exist in more littoral circumstances during Eocene times. This might be explained by the temperature of the water being more equable during the life of the fossil forms. those more susceptible to temperature variation having migrated to deeper water when conditions became unfavourable in the littoral zone.

While the otoliths of *Platycephalus, Sillago* and *Lactarius* approach most closely to those of the living East Indian species, suggesting a climate comparable with those parts, the occurrence of *Merluccius* indicates a more temperate influence. It seems probable that the climate existing during Tertiary times was subtropical.

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Explanation of Plate

PLATE XIII

Fig. 1.—*Platycephalus petilus* n.sp. Inner face. Miocene, Mitchell River, Victoria. P 13708. Dennant collection. × 6.

Fig. 2.—*Muraenesox obrutus* n.sp. Inner face. Balcombian, Clifton Bank, Muddy Creek, Victoria. P 16947. Dennant collection. × 6.

Fig. 3.—*Uroconger rectus* (Frost). Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16945. D. Curry collection. × 6.

Fig. 4.—*Sillago pliocaenica* Stinton. Inner face. Cheltenhamian, Cheltenham (= Beaumaris), Victoria. P 16965. Dennant collection. × 6.

Fig. 5.—*Lactarius tumulatus* n.sp. Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16964. D. Curry collection. × 6.

Fig. 6.—*Jordanicus exiguus* Stinton. Outer face. Miocene, Mitchell River, Victoria. P 17162. Dennant collection. × 6.

Fig. 7.—*Gadus refertus* n.sp. Inner face. Janjukian, Spring Creek, Victoria. P 16952. Dennant collection. × 6.

Fig. 8.—*Megalops lissa* n.sp. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16938. Inner face. D. Curry collection. × 12.

Fig. 9.—*Coelorhynchus elevatus* Stinton. Inner face. Balcombian, Balcombe Bay, Victoria. P 16955. R. W. T. Wilkins collection. × 6.

Fig. 10.—*Pleuronectes vulsus* n.sp. Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 13709. D. Curry collection. × 6.

Fig. 11.—*Jordanicus exiguus* Stinton. Inner face. Balcombian, Curlewis, Victoria. P 17161. Dennant collection. × 6.

Fig. 12.—*Uroconger rectus* (Frost). Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16944. D. Curry collection. × 6.

Fig. 13.—*Coelorhynchus elevatus* Stinton. Inner face. Balcombian. Beds H-K, Balcombe Bay, Victoria. P 16957. D. Curry collection. × 6.

Fig. 14.—*Ophidion granosum* n.sp. Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 13707. D. Curry collection. × 6.

Fig. 15.—*Gadus refertus* n.sp. Inner face. *Glycymeris* Beds, Bird Rock, Torquay, Victoria. P 16953. D. Curry collection. × 6.

Fig. 16.—*Astroconger rostratus* n.sp. Inner face. *Glycymeris* Beds, Bird Rock, Torquay, Victoria. P 16946. D. Curry collection. × 6.

Fig. 17.—*Coelorhynchus elevatus* Stinton. Outer face. Balcombian, Shelford, Victoria. P 16956. Dennant collection. × 6.

Fig. 18.—*Percidarum clivosum* n.sp. Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16963. D. Curry collection. × 12.

Fig. 19.—*Trachichthodes salebrosus* n.sp. Inner face. Juvenile. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16962. D. Curry collection. × 6.

Fig. 20.—*Heterenchelys regularis* n.sp. Inner face. Balcombian, Gellibrand Clay, Victoria. P 16948. Dennant collection. × 6.

Fig. 21.—*Pterothrissus pervetustus* n.sp. Inner face. Janjukian, Spring Creek, Victoria. P 16941. Dennant collection. × 6.

Fig. 22.—*Bregmaceros minutus* n.sp. Inner face. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16954. D. Curry collection. × 12.

Fig. 23.—*Megalops lissa* n.sp. Inner face, juvenile. Balcombian, Beds H-K, Balcombe Bay, Victoria. P 16949. D. Curry collection. × 12.

Fig. 24.—*Trachichthodes salebrosus* n.sp. Outer face. Balcombian, Shelford, Victoria. P 16961. Dennant collection. × 6.

Fig. 25.—*Monocentris sphaeroides* n.sp. Inner face. Aldinga, South Australia. P 16958. Dennant collection. × 6.

Fig. 26.—*Cleidopus cavernosus* n.sp. Inner face. *Limopsis* Beds, Torquay, Victoria. P 16959. D. Curry collection. × 6.

Fig. 27.—*Merluccius fimbriatus* n.sp. Inner face. Balcombian, Balcombe Bay, Victoria. P 16951. R. W. T. Wilkins collection. × 6.

Fig. 28.—*Trachichthodes salebrosus* n.sp. Inner face. Balcombian, Balcombe Bay, Victoria. P 16960. R. W. T. Wilkins collection. × 6.


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SOME TRILETE SPORES FROM UPPER MESOZOIC DEPOSITS IN THE EASTERN AUSTRALIAN REGION

By Isabel C. Cookson* and Mary E. Dettmann*

[Read 12 December 1957]

Abstract

Twenty-nine trilete microspore species are recorded; twenty-one of these are new types. New occurrences for four megaspores species are noted.

Evidence indicating a Lower Cretaceous (Albian) age for several Victorian deposits, three of which have previously been referred to the Lower Jurassic, is brought forward.

A correlation is established between the lower section of the Robe Bore and the Wonthaggi Coal Measures. It is suggested that the age of both deposits is Lower Cretaceous (Neocomian-Aptian).

Introduction

This paper is the outcome of early work on a long-term project which has for its ultimate aim the dating of the freshwater Mesozoic deposits of south-eastern Australia and Tasmania by palynological means. It is concerned partly with the identification and description of some of the more distinctive types of trilete microspores that occur in certain eastern Australian Upper Mesozoic sediments and partly with the stratigraphical implications to which they have given rise.

Until comparatively recently a Jurassic age has been accepted for all the freshwater Mesozoic deposits occurring in Victoria (the Triassic beds of the Bacchus Marsh area excepted) and the adjoining area of south-eastern South Australia. This age determination was originally based on the macroscopic plant remains which are frequently abundant in such Victorian deposits. In 1904, Seward compared the flora of the coal measures of these deposits with that of the Rajmahal Hills in India, while Medwell (1954a) after a re-examination of the flora as a whole came to the conclusion that it was of Lower Jurassic age.

The first intimation of the occurrence of Cretaceous deposits in Victoria was made by Kenley (1954) following the discovery of fragmentary dicotyledonous leaf-remains in the mudstone of the Runnymede Formation in south-western Victoria. The flora of this Formation was assigned to the Lower Cretaceous by Medwell (1954b.).

Concurrently, on palynological grounds, Cookson (1953, 1954) suggested a probable Cretaceous age for the lower section of the Birregurra Bore, 1,073-90 ft., and the sediments in the Comaum Bore, 651-708 ft., and soon afterwards Baker and Cookson (1955) recognized Upper Cretaceous sediments in the Nelson Bore of south-western Victoria, 5,782-6,192 ft.

On the evidence of megaspores, Cookson and Dettmann (1958) have suggested a Lower Cretaceous (Albian) rather than a Jurassic age for certain additional deposits in Victoria and South Australia. Some of the megaspores are referable to species which occur in Lower Cretaceous deposits in the Netherlands and England, others permit correlations with Australian deposits known, by their microplankton content, to be Lower Cretaceous.

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The individual microspore types and microspore assemblages to be considered below give added support to the Lower Cretaceous age-determinations previously mentioned, and clearly indicate a more extensive distribution of Cretaceous sediments in Victoria than was previously recognized.

Furthermore, they suggest that for the Victorian black coal measures, mentioned above, and beds of similar stratigraphic position, a Lower Cretaceous (Neocomian-Aptian) age.

Consideration has been restricted to trilete forms and the system of nomenclature suggested by Potonié (1956) for form-genera of such types has been followed throughout.

Unless otherwise specified, the polar dimensions included in the descriptions have been derived from at least ten examples.

Fig. 1.—Map of south-eastern Australia, showing location of deposits in which the Upper Mesozoic spore associations have been found. (Prepared by the Geological Survey of Victoria.)

Location and Age of Sediments

WESTERN AUSTRALIA. Carnarvon Basin, Exmouth Gulf area, Gearle Siltstone (lower part). West Australian Petroleum Pty. Ltd., Rough Range Well No. 1 at 2,750 ft. Age: Lower Cretaceous (Albian Cookson and Eisenack 1958. Perth Basin, Moora Bore 86-170 ft. Age: Lower Cretaceous (Albian) Cookson and Eisenack 1958. Canning Basin, Broome No. 1 Artesian Bore at 977 ft. Age: Upper Jurassic Cookson (unpublished).

SOUTH AUSTRALIA. Near Robe, northern portion of section 714, Hundred of Waterhouse. South Australian Oil Wells (No Liability), Bore No. 1, (a) 1,400-2,630 ft. Age: Lower Cretaceous (Albian) Cookson and Dettmann 1958. (b) 2,630-3,500 ft. Age: Jurassic (Ward 1917), Lower Cretaceous (Albian) authors. (c) 3,860-4,300 ft. Age: Jurassic (Ward 1917), Lower Cretaceous (Neocomian-Aptian) authors. Cootabarlow near Lake Frome, Bore No. 2 (a) at 581 ft. and 810 ft. Age: Lower Cretaceous (Albian) Cookson and Eisenack 1958. (b) at 1,354 ft. Age: Lower Cretaceous (Aptian) Cookson and Eisenack 1958. (c) at 1,465 ft. Age: Lower Cretaceous (Neocomian-Aptian) authors. Kopperamanna near Lake Frome, Bore No. 1 at 2,970 ft. Age: Lower Cretaceous (Neocomian-Aptian) Woodard 1955. Tilcha Bore near Lake Frome, at 460 ft. and 1,040 ft. Age: Lower Cretaceous (Albian) Cookson and Dettmann 1958. Loxton near Renmark, Australian Oil and Gas Corporation Ltd., Bore No. 1, at 1,410 ft. and 1,470 ft. Age: Lower Cretaceous (Albian) N. H. Ludbrook, South Australian Department of Mines Palaeontological Report—14/56, 1956 unpublished. Comaum, Hundred of Comaum, Bore No. 1, at 651 ft. and 708 ft. Age: Lower Cretaceous (possibly Albian) Cookson and Dettmann 1958.

VICTORIA. Nelson, Parish of Glenelg. Carbonaceous sediments from Victorian Department of Mines Bore at 4,782 ft., 6,233 ft., and 6,485-7 ft. Age: Upper Cretaceous Baker and Cookson 1955. Parish of Dergholm. Victorian Department of Mines Dergholm Bore No. 1 at 532 ft. and 582 ft. Age: Lower Cretaceous authors. Dergholm Bore No. 2 329-31 ft. Age: Lower Cretaceous (possibly Albian) Cookson and Dettmann 1958. Barongarook Creek, SW. of Colac. Age: Lower Cretaceous (Albian) Cookson and Dettmann 1958. Birregurra, Parish of Birregurra, carbonaceous sediments from Victorian Department of Mines Bore 1,070-80 ft., 1089-90 ft., and 1,101-2 ft. Age: Lower Cretaceous Cookson 1954. SE. of mouth of Gellibrand River, E. side of Devil's Kitchen, mudstone from near Mesozoic-Paleocene unconformity. Age: Lower Cretaceous (Albian) authors. Apollo Bay, shale containing *Cladophlebis denticulata*. Age: Lower Jurassic Medwell 1954, Lower Cretaceous (Neocomian-Aptian) authors. Bellarine Peninsula, near Geelong, Little's Shaft No. 2 38-47 ft. Age: Lower Cretaceous (Albian) Cookson and Dettmann 1958. Barrabool Hills, 1 m. SW. Fyansford, Geelong. Sample from outcrop along Barwon River. Age: Lower Jurassic Medwell 1954, Lower Cretaceous (?Albian) authors. San Remo Peninsula. Shale conatining *Taeniopteris hislopi* taken from above Coal Measures. Age: Lower Jurassic Medwell 1954, Lower Cretaceous (Neocomian-Aptian) authors. Cape Paterson, W. of Inverloch. Shore platform outcrop. Age: Lower Jurassic Medwell 1954, Lower Cretaceous (Neocomian-Aptian) authors. Whitelaw Railway Station, South Gippsland. Shale containing *Brachyphyllum gippslandicum* (N.M.V. P12805). Age: Lower Jurassic Medwell 1954, Lower Cretaceous (Neocomian-Aptian) authors. Wonthaggi State Coal Mine Area. (a) Victorian Department of Mines Bore No. 175 at 760 ft. Shale containing *Equisetites wonthaggiensis* (N.M.V. P12893). (b) Shale containing *Coniopteris hymenophylloides*. (c) West Area Mine. (1) Carbonaceous seam, west dip section, 400 ft., below sea level. (2)

Carbonaceous mudstone immediately above bottom seam. (3) Mudstone cuttings from floor of bottom coal seam. (d) No. 20 shaft. Carbonaceous mudstone from above top coal seam. (e) Kirrak Area. (1) Main coal seam, 103 ft. below sea level. (2) Mudstone from floor of coal seam. Age: Lower Jurassic Medwell 1954, Lower Cretaceous (Neocomian-Aptian) authors. Korumburra, Sunbeam Collieries. (a) Coal taken from seam at 350 ft. (b) Shale above coal seam. Age: Lower Jurassic Medwell 1954, Lower Cretaceous (Neocomian-Aptian) authors. Alberton, Parish of Alberton West. Victorian Department of Mines Bore No. 137, 174-8 ft., and Bore No. 159, 250-65 ft. Age: Jurassic Victorian Department of Mines Boring Records, 1951-2, published 1955, Lower Cretaceous (?Albian) authors. Berry Creek, Parish of Mardan, Victorian Department of Mines Bore No. 7, samples 10, 17, 18, 19, 65 and 68, and Bore No. 18 at 278 ft. Age: Lower Cretaceous (Neocomian-Aptian) authors. Tyers River, Latrobe Valley, Victorian Department of Mines Bore No. 2 850-1,200 ft. Age: Lower Cretaceous (Neocomian-Aptian) authors. Woodside, near Lakes Entrance. Woodside Well No. 2 sunk by Woodside (Lakes Entrance) Oil Company (No Liability), 4,114-27 ft., 4,251-7 ft., and at 6,402 ft. Age: Lower Cretaceous (Albian) authors. Hedley, near Lakes Entrance. Hedley Well No. 1 sunk by Woodside (Lakes Entrance) Oil Company (No Liability) at 1,460 ft., 2,099 ft., and 2,132 ft. Age: Lower Cretaceous (Albian) authors.

New South Wales. Onepah Station near Tibooburra. Soft fine-grained sandstone dug from a well at an unspecified depth. Age: Lower Cretaceous (Albian) Cookson and Eisenack 1958.

Queensland. Styx Coal Measures. Carbonaceous shales from Queensland Geological Survey's Bore No. 21, at 327 ft., and Bore No. 20, at 454 ft., sunk in the Tooloombah Creek area. Age: Lower Cretaceous (Albian) Walkom 1919, Cookson and Dettmann 1958. Near Weipa Mission, Albatross Bay, Gulf of Carpentaria. Zinc Corporation's Weipa No. 1 Bore, 2,022-41 ft. Age: Aptian authors.

New Guinea. Omati, Papua, Island Exploration Co.'s Bore, Samples 1 and 2. Age: Lower Cretaceous (Albian) Cookson and Eisenack 1958.

Systematic Descriptions

Turma Triletes Reinsch (1881) emend Potonié and Kremp 1954

Subturma Azonotriletes Luber 1935

Infraturma Laevigati Bennie and Kidston 1886

Genus **Divisisporites** Thomson 1952

Divisisporites euskirchenensis Thomson

(Pl. XIV, fig. 1)

Occurrence. South Australia—Robe Bore, at 1,400 ft.; Tilcha Bore, at 460 ft. Victoria—Birregurra Bore No. 1, at 1,102 ft.; Woodside Well No. 2, at 4,251 ft.

Geological Range in Australia. Lower Cretaceous (probable Albian).

Comments. This species was described by Thomson in Thomson and Pflug (1952) from Middle European Tertiary deposits (Paleocene) and subsequently recorded by Delcourt and Sprumont (1955) from the Wealden of Hainaut. The occurrence of *Divisisporites euskirchenensis* in Australian Lower Cretaceous sediments is therefore of interest.

D. euskirchenensis strongly resembles the Lower Cretaceous species *Cingulatisporites euskirchensoides* described by Delcourt and Sprumont (1955) from the

Wealden of Belgium and recorded later in this paper from Australia. It agrees with this form in size, and the subdivision of the tetrad scar only differing from it in the absence of a cingulum. In fact when, as often happens, the cingulum of *C. euskirchensoides* is imperfectly developed, it is difficult to decide which species is represented.

The above record of *D. euskirchenensis* is made therefore with some reservation, especially as the examples referred to it have been found only in deposits in which *C. euskirchensoides* is also present.

Infraturma Apiculati (Bennie and Kidston 1886)

Genus **Granulatisporites** (Ibrahim 1933)

Granulatisporites dailyi sp. nov.

(Pl. XIV, figs. 2-4; holotype, figs. 2, 3)

Occurrence. South Australia—Robe Bore, at 3,860 ft. and 4,300 ft.; Victoria—Barrabool Hills; Wonthaggi State Coal Mine Area, localities (a), (b), (c^3), (e^2); Korumburra shale above coal; Cape Paterson; Berry Creek Bore No. 7, samples 18, 65 and 68, Bore No. 18 at 278 ft.

Description. Spore trilete, tetrahedral (usually considerably flattened), broadly triangular to subcircular in polar view; tetrad-scar slightly raised, laesurae extending to the margin. Exine 2-4·5μ thick, the general surface finely granular, the proximal surface with three clusters of more clearly defined small granules situated at about the middle of the contact faces, the distal surface with a variable number of relatively large thickened areas of unequal size and shape.

Dimensions. Equatorial diameter 34-60μ.

Comments. Although *Granulatisporites dailyi* seems typical of the Lower Cretaceous (Neocomian-Aptian) deposits examined, it has been observed in the ? Albian deposit in the Barrabool Hills.

The specific name is given in honour of Mr. B. Daily, Paleontologist, South Australian Museum.

Genus **Leptolepidites** Couper 1953

Leptolepidites verrucatus Couper

(Pl. XIV, figs. 5, 6)

Occurrence. South Australia—Robe Bore, 3,325-4,300 ft.; Comaum Bore, at 708 ft.; Loxton Bore, at 1,410 ft. and 1,460 ft.; Cootabarlow Bore No. 2, at 1,354 ft. and 1,465 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Nelson Bore, at 6,485 ft.; Dergholm Bore No. 1, at 582 ft.; Bore No. 2, at 329 ft.; Birregurra Bore No. 1, at 1,102 ft.; Apollo Bay; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills; San Remo; Cape Paterson shale; Korumburra, shale above coal; Wonthaggi State Coal Mine Area, localities (b), (c^2), (c^3), (d), (e^2); Woodside Well No. 2, at 4,251 ft. and 6,402 ft. Queensland—Styx Coal Measures, Bore 21, at 327 ft. Papua—Omati Bore, samples 1 and 2 (Cookson and Eisenack 1958).

Comments. The relatively small (equatorial diameter 34-43μ) trilete, verrucate spores here referred to *Leptolepidites verrucatus* agree exactly with the description of this species as given by Couper (1953).

L. verrucatus is widely distributed in the eastern Australian region, but is most abundant in the Upper Mesozoic sediments of eastern Victoria. It ranges from Lower Cretaceous (Neocomian-Aptian) to Upper Cretaceous (Nelson Bore).

In New Zealand, *L. verrucatus* appears to be a rare type and to be restricted to the Jurassic.

Genus **Apiculatisporis** Potonié and Kremp 1956

Apiculatisporis wonthaggiensis sp. nov.

(Pl. XIV, figs. 7-10; holotype, fig. 8)

Occurrence. South Australia—Robe Bore, at 3,860 ft. Victoria—Apollo Bay; Wonthaggi State Coal Mine Area, localities (c^3), (e^2); Korumburra, shale above coal; Whitelaw Railway Station.

Description. Spore trilete, biconvex (usually much flattened) subcircular to subtriangular in polar view; tetrad-scar sometimes inconspicuous, laesurae extending to the margin. Exine *c.* 2-3μ thick, unevenly covered with small conical spinules which tend to be more widely spaced in the equatorial region.

Dimensions. Equatorial diameter 40-60μ.

Comments. Apiculatisporis wonthaggiensis seems to have a restricted distribution and to be confined to deposits of Lower Cretaceous (Neocomian-Aptian) age.

Apiculatisporis asymmetricus sp. nov.

(Pl. XIV, figs. 11, 12; holotype, fig. 11)

Occurrence. South Australia—Tilcha Bore No. 1, at 460 ft.; Robe Bore, at 1,400 ft. Victoria—Dergholm Bore No. 1, at 532 ft.; Birregurra Bore No. 1, at 1,102 ft. and 1,089 ft.; Gellibrand River (Devil's Kitchen); Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Woodside Well No. 2, at 4,251 ft. and 6,402 ft.; Hedley Well No. 1, at 2,099 ft. and 2,132 ft.; Papua—Omati Bore, sample 2 (Cookson and Eisenack 1958).

Description. Spore trilete, flattened; amb asymmetrical, subquadrangular to subtriangular with straight to slightly convex sides; tetrad-scar inconspicuous, laesurae extending almost to the margin. Exine about 2μ thick, densely covered with short broadly based spinules.

Dimensions. Equatorial diameter 36-52μ.

Comments. Apiculatisporis asymmetricus can be distinguished from *A. wonthaggiensis* by its asymmetrical and rather straight-sided amb and the denser arrangement and broader bases of the spinules.

Some of the deposits in which *A. asymmetricus* occurs are known to be of Albian age while the age of others is less certain. However, correlation between the microfloras of the dated and undated deposits suggests that all are of approximately Albian age.

Genus **Osmundacidites** Couper 1953

Osmundacidites comaumensis (Cookson)

(Pl. XIV, fig. 13)

Trilites comaumensis Cookson 1953. *Aust. J. Bot.* 1: 470 (Pl. II, figs. 27, 28).
Baculatisporites comaumensis (Cookson) Potonié 1956. *Geol. Jahrb.* 23: 33.
Osmundacidites comaumensis (Cookson) Balme 1957. *C.S.I.R.O. Coal. Res. Sect.* T.C. 25 (Pl. IV, figs. 54-6).

Occurrence. South Australia—Comaum Bore, at 708 ft.; Cootabarlow Bore No. 2, at 1,354 ft., 1,465 ft.; Tilcha Bore No. 1, at 1,040 ft.; Kopperamanna Bore, at 2,970 ft.; Loxton Bore, at 1,410 ft.; Robe Bore, 1,780-4,300 ft.; Comaum Bore, 651-708 ft. Victoria—Nelson Bore, at 5,782 ft., 6,233 ft., and 6,485-7 ft.; Dergholm Bore No. 1, at 582 ft., Bore No. 2, at 329 ft.; Apollo Bay; Birregurra Bore No. 1, 1079-102 ft.; Barongarook Creek; Barrabool Hills; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; San Remo; Wonthaggi State Coal Mine Area, localities (a), (b), (c), (d), (e); Korumburra shale above coal; Cape Paterson, Tyers Bore No. 2, 860-1,200 ft.; Berry Creek Bore No. 7, samples 17, 18, 19, 65, 68, and

Bore No. 18, at 278 ft.; Whitelaw Railway Station; Alberton West Bore No. 137, at 174 ft.; Woodside Well No. 2, at 4,251 ft. and 6,402 ft. Queensland—Styx Coal Measures Bore No. 20, at 454 ft., Bore No. 21, at 327 ft.

Comments. When *Osmundacidites comaumensis* was first described a holotype was not designated. The syntype shown in Pl. II, fig. 28 of Cookson's paper (1953) is herewith distinguished as the holotype and refigured in Pl. XIV, fig. 13.

O. comaumensis is a common and readily recognizable species which during the present investigation has ranged from Lower Cretaceous (Neocomian-Aptian) to Upper Cretaceous. It has been identified by Balme (1957) in Upper Jurassic and Cretaceous deposits in Western Australia and a closely similar form has been isolated from Quaternary deposits near Melbourne, Duigan and Cookson (1957).

Genus **Neoraistrickia** Potonié 1956

Neoraistrickia truncatus (Cookson)

(Pl. XIV, figs. 14-16; holotype, fig. 14)

Trilites truncatus Cookson 1953. *Aust. J. Bot.* 1: 471 (Pl. II, fig. 36).
Neoraistrickia truncatus (Cookson) Potonié 1956. *Geol. Jahrb.* 23: 34.

Occurrence. South Australia—Robe Bore, 3,325-4,300 ft.; Cootabarlow Bore No. 2, at 1,354 ft. and 1,465 ft.; Comaum Bore, 651-708 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Apollo Bay; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills; Wonthaggi State Coal Mine Area, localities (a), (b), (c^3), (e^2); Cape Paterson; Berry Creek Bore No. 7, samples 17, 65, 68 and 72, Bore 18, at 278 ft.; Tyers Bore No. 2, at 860 ft., 1,000 ft. and 1,100 ft.; San Remo; Whitelaw Railway Station; Alberton West Bore No. 137, at 174 ft.

Comments. The original description of *N. truncatus* is as follows: "Spore tetrahedral, trilete, subtriangular in polar view, about 31-55μ in diameter; exospore ornamented with coarse, evenly spaced truncate processes about 3·5μ long, tetrad-scar reaching the periphery."

Upon the study of further specimens from the type locality it has been discovered that the processes are not equally developed over the entire surface of the spore, but on the proximal surface are less numerous, thinner and baculate. The larger truncate processes of the distal surface are from 3-5μ long and broaden considerably towards their points of insertion; the tetrad-scar is slightly raised above the surface.

Geological Range. Neocomian-Aptian to Albian.

Comments. N. truncatus differs from *N. neozealandica* (Couper) of New Zealand Jurassic beds in shape, the stronger development of the tetrad-scar and the smaller size of the truncate processes.

Genus **Ceratosporites** gen. nov.

Description. Spore tetrahedral, trilete, distal surface ornamented by blunt or sharply pointed processes, proximal surface smooth.

Genotype. Ceratosporites equalis sp. nov.

Ceratosporites equalis sp. nov.

(Pl. XIV, figs. 17-20; holotype, figs. 17-19)

Occurrence. South Australia—Cootabarlow Bore No. 2, at 1,354 ft. and 1,465 ft.; Robe Bore, 3,325-4,300 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Bellarine, Little's Shaft No. 2, 38-47 ft.; Apollo Bay; San Remo; Cape Paterson; Wonthaggi State Coal Mine Area, localities (a), (b), (c^3), (d), (e^2); Korumburra shale above coal seam; Whitelaw Railway Station; Berry Creek Bore No. 18, at 278 ft., and

Bore 7, samples 10, 17, 18, 19, 65 and 68; Tyers Bore No. 2, 850-1,150 ft.; Alberton West Bore No. 137, at 174 ft. Queensland—Styx Coal Measures, Bore No. 21, at 327 ft.

Description. Spore tetrahedral, trilete, subtriangular in polar view; tetrad-scar prominent and raised by a low tecta, laesurae extending to the margin. Exine thin, proximal surface unornamented, distal surface with rather closely spaced thin, straight-sided, blunt, capitate or occasionally bifurcate processes.

Dimensions. Equatorial diameter 32-52μ, processes 3-7μ long, 1-2μ wide.

Comments. The affinity of *Ceratosporites equalis* appears to be with the Lycopodiales and more particularly with the Selaginellaceae. In the nature and distribution of the ornament, it resembles spores of the *Selaginella latifron* group (Knox 1950) and to a lesser extent those of *Lycopodium densum* La Billard (Knox 1950)

The geological range of *C. equalis* is from Neocomian-Aptian to Albian, but so far it has not been recovered from the typical Albian deposits of the Artesian Basin.

Genus **Pilosisporites** Delcourt and Sprumont 1955

Pilosisporites notensis sp. nov.

(Pl. XV, figs. 1-3; holotype, fig. 1)

Occurrence. South Australia—Robe Bore, 4,300-1,400 ft.; Cootabarlow Bore No. 2, 1,354-581 ft.; Tilcha Bore, at 1,040 ft. and 460 ft.; Loxton Bore, at 1,470 ft.; Comaum Bore, at 708 ft. Victoria—Nelson Bore, at 6,485 ft.; Dergholm Bore No. 1, at 532 ft.; Barongarook Creek near Colac; Apollo Bay; Barrabool Hills; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Berry Creek Bore No. 18, at 278 ft.; Cape Paterson; Wonthaggi State Coal Mine Area, localities (a), (b), (c^3), (e^2); Korumburra shale above coal seam; Woodside Well No. 2, at 4,251 ft.; Hedley Well No. 2, at 4,251 ft.; Hedley Well No. 1, at 2,132 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore No. 21, at 327 ft., and Bore No. 20, at 454 ft.; Weipa Bore No. 1, 2,022-41 ft.

Description. Spore trilete with a convex distal surface, a somewhat flattened proximal surface and a triangular amb with broadly rounded angles and straight to slightly concave sides. The laesurae of the tetrad-scar are distinctly rimmed and do not reach the equator. The exine is about 2·5-3·5μ thick, and invested with short straight-sided hairs or broad-based spinules *c.* 1·5-5μ long which are more densely arranged around the angles than on the proximal and the distal surfaces. Frequently, they are linearly arranged around the laesurae of the tetrad-scar.

Dimensions. Equatorial diameter 95-125μ; polar diameter of specimen shown in Pl. XIV, fig. 3, 81μ.

Comments. Pilosisporites notensis resembles, to some extent, the Belgian Wealden species *P. verus* Delcourt and Sprumont, but differs from it in having shorter and more evenly distributed surface projections. In *P. verus* the ornament takes the form of relatively long spines which are restricted to the angles of the spore whereas in *P. notensis*, it is in the form of more evenly distributed short hairs or spinules.

P. notensis is one of the most widely distributed types in the Upper Mesozoic deposits of eastern Australia and has been recovered from Lower Tertiary deposits in the Nelson Bore at 2,874 ft. and the Dartmoor Formation in south-western Victoria. Many of the Mesozoic deposits in which *P. notensis* occurs are now known to be of Albian age (Cookson and Dettmann 1958). Others, such as the freshwater shales associated with the black coal seams at Wonthaggi and Korumburra, which were previously assigned to the Lower Jurassic (Medwell 1954) on the basis of the contained macro plant remains are herein tentatively referred to as Lower Cretaceous (Neocomian-Aptian).

Genus **Kulyisporites** Potonié

Kulyisporites lunaris sp. nov.

(Pl. XIV, figs. 21-3; holotype, figs. 22, 23)

Occurrence. Victoria—Barrabool Hills; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Berry Creek Bore No. 18, at 278 ft.; Tyers Bore No. 2, at 860 ft.; Wonthaggi State Coal Mine Area, localities (b), (e^2).

Description. Spore trilete, equatorial outline varying from almost circular to subquadrangular or subtriangular with straight or convex sides; the laesurae of the tetrad-scar extend to the margin but are more prominent in the polar area. Exine finely granular, usually with a few coarser granules on each contact face. The most conspicuous feature is the presence on both proximal and distal surfaces of half-moon shaped ridges or scutula, the number of which may be the same on both surfaces, or greater on the distal surface than on the proximal surface, the number varies from 1-3 per contact area.

Dimensions. Equatorial diameter 30-54μ; diameter of areas enclosed by the scutula from 5-7μ.

Comments. The occurrence of small scutula on the spore surface of *Kulyisporites lunaris* is reminiscent of the spores of certain living species of *Hemitelia* and of the type from the Upper Tertiary of Trinidad referred to as "*Hemitelia* type", by Kuyl, Muller and Waterbolk (1955), and as *Kulyisporites waterbolki* by Potonié (1956). However, in *K. lunaris*, the scutula appear to be restricted to the polar surfaces whereas in *Hemitelia grandifolia* Willd., for example, they are situated, according to Erdtman (1943), "either near the margin of the distal part of the grain, or in the transition between the distal and the proximal part".

K. lunaris has been recovered only from a few Victorian deposits, the age of which ranges from Neocomian-Aptian to Albian.

Infraturma MURORNATI Potonié and Kremp 1954

Genus **Radiatisporites** gen. nov.

Description. Spore trilete with an open-meshed reticulum, the muri of which are considerably elongated, those of the proximal surface radiating from the laesurae of the tetrad-scar to the periphery, those of the distal surface lying either tangentially or obliquely to the margin.

Genotype. Radiatisporites hughesi sp. nov.

Radiatisporites hughesi sp. nov.

(Pl. XV, figs. 4-6; holotype, fig. 4)

Occurrence. South Australia—Robe Bore, at 3,860 ft. and 4,300 ft.; Comaum Bore, at 708 ft.; Cootabarlow Bore No. 2, at 1,465 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Cape Paterson; Wonthaggi State Coal Mine Area, localities (a), (b), (c); Korumburra shale above coal; Whitelaw Railway Station; Berry Creek Bore No. 7, samples 17, 18, 65, and 68.

Description. Spore trilete, amb subtriangular to subcircular, laesurae of tetrad-scar extending to the margin. Exine thin, ornamented on both surfaces by a deep reticulum having narrow, elongated, sometimes sinuous muri and wide lumina. On the proximal surface the muri radiate from a thickened ridge which runs parallel to the laesurae of the tetrad-scar and sometimes bifurcate before reaching the margin (Pl. XV, fig. 4); on the distal surface their direction is variable (Pl. XV, fig. 6).

Dimensions. Equatorial diameter 40-65μ; lumina of reticulum, proximal surface *c*. $5\mu \times 20\mu$, distal surface *c*. $6\mu \times 22\mu$.

Geological Range. Lower Cretaceous (Neocomian-Aptian).

The specific name is in honour of Mr. N. F. Hughes, Sedgwick Museum, Cambridge.

Genus **Ischyosporites** Balme 1957

Ischyosporites scaberis sp. nov.

(Pl. XV, figs. 7-9; holotype, figs. 8-9)

Occurrence. South Australia—Robe Bore, 4,300-2,630 ft.; Loxton Bore, at 1,470 ft. and 1,410 ft.; Comaum Bore, at 708 ft. Victoria—Dergholm Bore No. 1, at 532 ft.; Gellibrand River (Devil's Kitchen); Apollo Bay; Bellarine, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills; San Remo; Wonthaggi State Coal Mine Area, localities (a), (b), (c^1), (c^3), (e^2), (d); Cape Paterson; Tyers Bore No. 2, 860-1,200 ft.; Berry Creek Bore No. 7, samples 17, 18, 19, 65, 68, Bore 18, at 278 ft.; Whitelaw Railway Station; Alberton West Bore No. 137, at 174 ft.; Woodside Well No. 2, at 4,251 ft. and 6,402 ft. Queensland—Styx Coal Measures Bore No. 20, at 454 ft.

Description. Spore trilete, amb broadly triangular to subcircular, sides convex; tetrad-scar not strongly marked, laesurae reaching the margin. Exine 4-6μ thick, proximal surface with coarse granules and low broad sinuous ridges, distal surface granular and with coarse ridges of uneven width (*c*. 4-7μ wide) which anastomose to form a more or less perfect reticulum.

Dimensions. Equatorial diameter 38-54μ; diameter of lumina of reticulum 4-11μ.

Comments. *Ischyosporites scaberis* differs from the genotype *I. craterus* Balme from West Australian Upper Mesozoic deposits in having a roughened and evenly thickened exine.

I. scaberis has a wide geographical distribution in eastern Australia; its geological range is from Neocomian-Aptian to Albian, but it is more frequent in the older deposits.

Ischyosporites punctatus sp. nov.

(Pl. XVI, figs. 1-4; holotype, fig. 1)

Occurrence. Western Australia—Broome No. 1 Bore, at 977 ft. South Australia—Cootabarlow Bore No. 2, 1,354-465 ft.; Kopperamanna Bore, at 2,970 ft.; Loxton Bore, at 1,410 ft. Victoria—Wonthaggi State Coal Mine, locality (b).

Description. Spore tetrahedral, trilete, amb triangular with more or less straight sides; laesurae almost reaching the periphery. Exine 2-3μ, thicker (3-5μ) at the angles, ornamented on the distal surfaces by an irregular reticulum with heavy muri and widely spaced lumina, the diameter of which range from 2-6μ; proximal surface punctate in the vicinity of the tetrad-scar otherwise unornamented.

Dimensions. Equatorial diameter 52-63μ.

Comments. This is a rare type in south-eastern Australian deposits. Apart from the single specimen recovered from the Albian deposit in the Loxton Bore at 1,410 ft., it seems to be restricted to Lower Cretaceous (pre-Albian) deposits. In Western Australia it has been observed in the Aptian deposit intersected by the Attadale Artesian Bore in the Perth metropolitan area at 809 ft., and in Upper Jurassic sediments in the Broome No. 1 Bore at 977 ft.

I. punctatus is readily distinguishable from *I. craterus* and *I. scaberis* by the fine pitting on the proximal surface.

Genus **Lycopodiumsporites** Thiergart 1938

Lycopodiumsporites austroclavatidites (Cookson)

(Pl. XV, fig. 12)

Lycopodium austroclavatidites Cookson 1953. *Aust. J. Bot.* 1: 469 (Pl. II, fig. 35).
Lycopodiumsporites austroclavatidites (Cookson) Potonié 1956. *Geol. Jahrb.* 23: 46.

Occurrence. South Australia—Robe Bore, 1,780-4,300 ft.; Cootabarlow Bore No. 2, at 1,354 ft. and 1,465 ft.; Comaum Bore, 651-708 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Birregurra Bore No. 1, at 1,089 ft. and 1,102 ft.; Barrabool Hills; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Cape Paterson; Wonthaggi State Coal Mine Area, localities (a), (b), (c), (d), (e^2); Korumburra, shale above coal; Whitelaw Railway Station; Berry Creek Bore No. 18, at 278 ft., Bore No. 7, samples 17, 65 and 68; Alberton West Bore No. 137, at 174 ft.

Comments. Spores which may be referred to this species are common throughout the Upper Mesozoic sediments examined during this investigation and therefore appear to be of little stratigraphical value. The rephotographed holotype is illustrated in Pl. XV, fig. 12.

Lycopodiumsporites circolumenus sp. nov.

(Pl. XV, figs. 10, 11; holotype, figs. 10, 11)

Occurrence. Western Australia—Broome No. 1 Bore, at 977 ft. South Australia—Cootabarlow Bore No. 2, 1,354-465 ft.; Kopperamanna Bore, at 2,970 ft.; Robe Bore, 3,860-4,300 ft. Victoria—Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; San Remo; Wonthaggi State Coal Mine Area, localities (a), (b), (d); Berry Creek Bore No. 7, samples 18, 65; Whitelaw Railway Station, Woodside Well No. 2, at 6,402 ft.

Description. Microspore trilete, biconvex, amb subtriangular to almost circular. Tetrad-scar prominent, the laesurae sinuous, raised by a low tecta and extending to the margin. Exine *c.* 2-3μ thick, smooth on the proximal surface and reticulate on the distal surface. The muri of the reticulum are *c.* 1-2μ wide and enclose almost circular or sometimes polygonal lumina *c.* 4-7μ in diameter.

Dimensions. Equatorial diameter 45-60μ.

Comments. Of the species of *Lycopodiumsporites*, *L. circolumenus* seems closest to *L. agathoecus* (R. Potonié) Thiergart. However, it differs from this species in the nature of the tetrad-scar and smaller size. Although *L. circolumenus* has been recovered from the Albian deposit in Little's Shaft, Bellarine Peninsula, it seems to be more typical of the older Neocomian-Aptian deposits. In Western Australia it has been observed in the Aptian deposit in the Attadale Bore at 999 ft., and in the Upper Jurassic deposit in the Broome No. 1 Bore at 977 ft.

Genus **Cicatricosisporites** Potonié and Gelletich 1933

Cicatricosisporites australiensis (Cookson)

(Pl. XV, figs. 13, 14; holotype, fig. 13)

Mohriorisporites australiensis Cookson 1953. *Aust. J. Bot.* 1: 470 (Pl. II, figs. 31-4).
Cicatricosisporites australiensis (Cookson) Potonié 1956. *Geol. Jahrb.* 23: 48.

Occurrence. South Australia—Robe Bore, 1,400-3,860 ft.; Cootabarlow Bore No. 2, at 581 ft., 810 ft. and 1,354 ft.; Tilcha Bore, at 460 ft. and 1,040 ft.; Loxton Bore, at 1,410 ft. and 1,470 ft.; Comaum Bore, at 651 ft. and 708 ft. Victoria—Dergholm Bore No. 1, at 532 ft., Bore No. 2, at 329 ft.; Barongarook Creek; Birregurra Bore No. 1, at 1,089 ft. and 1,102 ft.; Gellibrand River (Devil's Kitchen); Apollo Bay; Nelson Bore No. 1, 5,782-6,485 ft.; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills; Wonthaggi State Coal Mine Area, localities

(a), (b), (c^3), (e^2); Korumburra above coal seam; Cape Paterson; Berry Creek Bore No. 7, samples 18 and 19, Bore 18, at 278 ft.; Tyers Bore No. 2, 850-1,200 ft.; Whitelaw Railway Station; Woodside Well No. 2, 4,117-6,402 ft.; Hedley Bore No. 1, 1,460-2,132 ft.; Alberton West Bore No. 137, 174-8 ft., Bore 159, 250-65 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore No. 21, at 327 ft., Bore No. 20, at 454 ft. Papua—Omati Bore, samples 1 and 2 (Cookson and Eisenack 1958).

Description. For completeness, the diagnosis of *Cicatricosisporites australiensis* as given by Cookson (1953) has been included. "Spores tetrahedral with rounded angles; trilete 35-50 × 29-34μ, tetrad-scar reaching the periphery, exospore ornamented with narrow ridges which run parallel to the walls of the spore." This description was accompanied by illustrations of four syntypes. In the absence of a specified holotype we designate the example shown in Cookson's Pl. II, fig. 32 as holotype and refigure it in Pl. XV, fig. 13.

Comments. Cicatricosisporites australiensis has been found to be one of the most wide-spread of the trilete species present in the Cretaceous beds of the eastern Australian region, with a southerly extension from Papua to southern Victoria and South Australia. Most of the deposits in which *C. australiensis* occurs are Lower Cretaceous but in Victoria it is known from the Upper Cretaceous section of the Nelson Bore (Baker and Cookson 1955) and during this investigation has been isolated from Victorian Upper Mesozoic coals and their associated shales which were assigned to the Lower Jurassic by Medwell (1954a) and are herein referred to as Neocomian-Aptian.

In Papua, *C. australiensis* occurs in the upper samples of the Albian-Aptian section of the Omati core but not in the Upper Jurassic section. In Queensland, *C. australiensis* is relatively abundant in the Lower Cretaceous (Albian) Styx Coal Measures, less frequent in the slightly older Burrum coals and absent altogether, as Dr. N. J. de Jersey has kindly informed us, from the Rosewood coals (Lower Jurassic).

Similarly in South Australia, a numerical decrease with depth is noticeable in both the Robe and Cootabarlow Bores. In the latter *C. australiensis* is well represented in the Albian deposit intersected at 581 ft., infrequent in the Aptian deposit at 1,354 ft. and apparently absent from the sample taken at 1,465 ft.

The occurrence of *C. australiensis* in Western Australia seems to be less frequent than it is in eastern Australia. Balme (1957) reports that it "was not found in any of the samples known definitely to be pre-Cretaceous and was rare in assemblages in which it did occur in Western Australia". More recently, the same author (Balme pers. comm.) has noted fairly large numbers of the species in sediments immediately underlying the Molecap Greensand in the Gingin area. The age of these sediments is uncertain but from their stratigraphical relationships they can hardly be older than Aptian.

From the above, it is evident that, while *C. australiensis* is typically a Cretaceous species, it cannot be used, at least in Victoria, as an index of Cretaceous age while the present uncertainty exists regarding the age of the Wonthaggi deposits.

Genus **Dictyotosporites** gen. nov.

Description. Microspore trilete, tetra-scar inconspicuous prior to opening, laesurae reaching or almost reaching the margin. Exine ornamented on both surfaces by a reticulate membrane, consisting of a primary reticulum and one or more superimposed reticula.

Genotype. Dictyotosporites specious.

Dictyotosporites speciosus sp. nov.

(Pl. XVI, figs. 5-10; holotype, fig. 5)

Occurrence. South Australia—Robe Bore, at 3,860 ft. and 4,300 ft.; Cootabarlow Bore No. 2, at 1,354 ft. and 1,465 ft.; Comaum Bore, at 708 ft. Victoria—Apollo Bay; Cape Paterson; Whitelaw Railway Station; Wonthaggi State Coal Mine Area, localities (a), (b), (c^3), (e^1), (e^2); Korumburra locality (a); Berry Creek Bore No. 7, sample 19.

Description. Spore trilete, distal surface convex; proximal surface almost flat; amb broadly triangular to almost circular; laesurae of tetrad-scar unthickened sometimes reaching the periphery. Exine 2-7μ thick, consisting of an inner apparently homogeneous layer from which the primary muri arise and an outer lace-like zone consisting of one or two finer reticula formed as the result of the fusion of the subdivisions of the primary and secondary muri respectively.

Dimensions. Overall equatorial diameter 41-63μ; equatorial diameter 37-55μ.

Geological Range. Lower Cretaceous (pre-Albian).

Dictyotosporites complex sp. nov.

(Pl. XVI, figs. 11-16; holotype, fig. 11. Pl. XVIII, fig. 1)

Occurrence. South Australia—Robe Bore, at 3,860 ft.; Cootabarlow Bore No. 2, at 1,465 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Wonthaggi State Coal Mine Area, locality (b).

Description. Spore trilete, biconvex, amb approximately circular, tetrad-scar inconspicuous, laesurae reaching the periphery. Exine of variable width consisting of two layers, an inner thin, apparently homogeneous layer and an outer reticulate membrane, composed of two or more superimposed reticula. The lumina of the outer membrane are always minute and either uniform or variable in size in which case the smallest are always those adjacent to the spore wall. The outer network is attached to the inner layer of the exine by thread-like processes which bifurcate distally. (Pl. XVI, figs. 15, 16.)

Dimensions. Overall equatorial diameter 42-69μ; equatorial diameter of spore 35-45μ; width of reticulate membrane 4-15μ.

Comments. Dictyotosporites complex can be distinguished from *D. speciosus* in having a thinner and more transparent reticulate outer membrane, more delicate primary exinous outgrowths and in an increase rather than a decrease in the size of the mesh towards the margin.

In typical examples of *D. complex*, the mesh of the reticulate membrane is so small that it can be seen only at a magnification of 1,000 or more diameters. In the spores shown in Pl. XVI, figs. 12, 16, both of which appear to have the same type of construction as *D. complex*, the meshwork is clearly visible at a magnification of about 500 diameters. It is possible that these spores may represent another species. However, until the limits of variation in this respect can be more clearly defined by the study of a larger number of examples of both types, the two apparently atypical forms are compared rather than identified with *D. complex*.

Some difficulty has been experienced in the morphological interpretation of *D. complex*. When first observed it was thought that the reticulate covering of the spore was in the nature of a perine. However, the later discovery of numerous thread-like supporting projections from the surface of the inner apparently homogeneous layer of the exine of a specimen from which the reticulate membrane had been partially detached has proved it to be exinous in origin (Pl. XVI, figs. 15, 16).

In eastern Australia *D. complex* seems to be restricted to deposits of Lower Cretaceous (Neocomian-Aptian) age. The authors have also observed it in sediments situated at 963-77 ft. in the Broome No. 1 Artesian Bore in Western Australia, the age of which, on the grounds of the contained microplankton, is almost certainly uppermost Jurassic.

Infraturma PERINOTRILITI Erdtman 1947

Genus **Perotrilites** (Erdtman) ex Couper 1953

Perotrilites striatus Cookson and Dettmann

(Pl. XVI, figs 17-18)

Occurrence. South Australia—Robe Bore, 3,500-1,400 ft.; Cootabarlow Bore No. 2, at 581 ft. and 810 ft.; Tilcha Bore, at 1,040 ft. and 460 ft.; Loxton Bore, at 1,410 ft.; Comaum Bore, at 708 ft. Victoria—Dergholm Bore No. 1, at 582 ft. and 532 ft., Bore No. 2, at 329 ft.; Barongarook Creek; Birregurra Bore No. 1, at 1,089 ft., 1,099 ft. and 1,102 ft.; Gellibrand River (Devil's Kitchen); Barrabool Hills; Bellarine Peninsula, Little's Shaft No, 2, 38-47 ft.; Woodside Well No. 2, at 6,402 ft.; Hedley Well No. 1, at 2,132 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore No. 21, at 327 ft., Bore No. 20, at 454 ft. Papua—Omati Bore, samples 1 and 2 (Cookson and Eisenack 1958).

Comments. When this species was described (Cookson and Dettmann 1958) only those localities in which the megaspore genus *Pyrobolospora* Hughes also occurred, were recorded. *Perotriletes striatus* has a wide geographical distribution in the eastern Australian region but appears to have a restricted geological range. So far all the deposits in which it has been found are Lower Cretaceous and mostly Albian.

P. striatus seems to have a close connection with the species of *Pyrobolospora* which, almost invariably, are to be found in the same deposits, and frequently has been observed amongst the proximal "leaves" which characterize these genus. The affinity of *P. striatus* with the Hydropteridae has already been discussed (Cookson and Dettmann 1958).

Subturma PYROBOLOTRILETES R. Potonié 1956

Genus **Pyrobolospora** Hughes

Pyrobolospora reticulata Cookson and Dettmann

During the present investigation examples of this type of megaspore have been found in three additional Victorian deposits. Its known distribution is now as follows: South Australia—Robe Bore, at 1,400 ft.; Cootabarlow Bore No. 2, at 581 ft.; Loxton Bore, at 1,410 ft.; Tilcha Bore, at 1,040 ft. Victoria—Dergholm Bore No. 1, at 532 ft., Bore No. 2, at 329 ft.; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft. New South Wales—Onepah Station Well.

P. reticulata appears to be restricted to deposits of Albian age.

Pyrobolospora nuda Cookson and Dettmann 1958

This species which was originally described from the Tilcha Bore at 460 ft., has since been recovered from the Robe Bore at 1,400 ft.

? Subturma PYROBOLOTRILETES Potonié 1956

Genus **Balmeisporites** Cookson and Dettmann

Balmeisporites holodictyus Cookson and Dettmann

The distribution of this species has been somewhat extended during the present investigation and is now known to include the following deposits: South Australia—Robe Bore, at 1,400 ft. and 1,780 ft.; Loxton Bore, at 1,410 ft.; Cootabarlow Bore No. 2, at 581 ft.; Tilcha Bore, at 460 ft. and 1,040 ft. Victoria—Barongarook Creek; Birregurra Bore No. 1, at 1,089 ft. and 1,102 ft.; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore 21, at 327 ft., Bore 20, at 454 ft. Papua—Omati Bore No. 1, sample 2.

All these deposits are of Lower Cretaceous (probably Albian) age.

Turma ZONALES (Bennie and Kidston 1886) R. Potonié 1956

Subturma AURITOTRILETES Potonié and Kremp

Infraturma AURICULATI (Schopf) Potonié 1954 and Kremp 1954

Genus **Trilobosporites** (Pant) ex Potonié 1956

Trilobosporites trioreticulosus sp. nov.

(Pl. XVII, figs. 1-3; holotype, fig. 3)

Occurrence. South Australia—Cootabarlow Bore No. 2, at 1,354 ft. and 810 ft.; Tilcha Bore, at 1,040 ft. and 460 ft.; Robe Bore, 1,780 ft. and 1,400 ft. Victoria—Barongarook Creek; Birregurra Bore, at 1,102 ft.; Gellibrand River (Devil's Kitchen); Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore No. 21, at 327 ft., Bore No. 20, at 454 ft.

Description. Spore trilete; amb triangular with broadly rounded angles and straight to slightly concave sides; the laesurae of the tetrad-scar are usually strongly rimmed and extend about half-way to the equator. The exine is about $2{\cdot}5$-3μ thick and closely covered with scabrae or coarse granules. In addition a shallow reticulum with polygonal lumina and coarse and somewhat sinuous muri is developed at and around the angles of the spore.

Dimensions. Equatorial diameter 70-85μ.

Geological Range. Lower Cretaceous (Albian-Aptian).

Comments. Trilobosporites trioreticulosus is readily distinguishable from other trilete microspores by the coarse reticulum present at the angles. It seems to have a more restricted vertical distribution than many of the Australian Upper Mesozoic microspores, present indications pointing to an Albian-Aptian time range.

Subturma ZONOTRILETES Waltz 1935

Infraturma CINGULATI R. Potonié and Klaus 1954

Genus **Cingulatisporites** Thomson 1953

Cingulatisporites euskirchensoides Delcourt and Sprumont

(Pl. XVII, figs. 4-6)

Occurrence. Western Australia—Moora Bore, 86-170 ft. South Australia—Cootabarlow No. 2 Bore, at 1,354 ft. and 581 ft.; Tilcha Bore, at 1,040 ft.; Loxton Bore, at 1,410 ft.; Robe Bore, at 3,500 ft., 3,325 ft., 2,325 ft., 1,780 ft. and 1,400 ft.

Victoria—Birregurra Bore No. 1, at 1,102 ft., 1,096 ft. and 1,089 ft.; Dergholm Bore No. 1, at 532 ft., Bore No. 2, at 329 ft.; Barongarook Creek; Gellibrand River (Devil's Kitchen); Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Tyers Bore No. 2, at 860 ft.; Woodside Well No. 2, at 4,251 ft. New South Wales—Onepah Station. Queensland—Styx Coal Measures Bore No. 20, at 454 ft. Papua—Omati Bore, sample 2 (Cookson and Eisenack 1958).

Description. The spores referred to *Cingulatisporites euskirchensoides* are rounded to ovoid in polar view and have a delicate equatorial flange from *c.* $2 \cdot 5$-5μ wide and a more or less branched tetrad-scar. The exine is *c.* $1 \cdot 5\mu$ thick, and finely granular.

Dimensions. The equatorial diameter of the spore is 40-55μ and the overall equatorial diameter 50-60μ.

Comments. The Australian representatives of *C. euskirchensoides* agree closely with the examples described in 1955 by Delcourt and Sprumont from Wealden deposits in Hainaut, Belgium. They are widely distributed throughout eastern Australia and extend to Papua, New Guinea, but seem to be restricted to beds of Albian-Aptian age.

Cingulatisporites simplex sp. nov.

(Pl. XVII, figs. 7, 8; holotype, fig. 8)

Occurrence. South Australia—Tilcha Bore, at 1,040 ft.; Robe Bore, at 2,630 ft. and 1,400 ft. Victoria—Dergholm Bore No. 1, at 532 ft.; Birregurra Bore No. 1, at 1,102 ft., 1,096 ft. and 1,089 ft.; Barongarook Creek; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.

Description. Spores trilete rounded to ovoid in polar view with a finely granular, transparent, equatorial flange of uneven width (*c.* $1 \cdot 5$-5μ). Exine *c.* 3μ thick, smooth; tetrad-scar distinct, the laesurae unbranched, extending either to or almost to the equator.

Dimensions. Equatorial diameter of spore 40-58μ; overall equatorial diameter 43-65μ.

Geological Range. Lower Cretaceous (probably Albian).

Comments. Cingulatisporites simplex is very similar to *C. euskirchensoides* Delcourt and Sprumont from the Wealden of Belgium only differing from this species in having an unbranched tetrad-scar. There is little doubt that the two forms are closely related and it is even possible that they are variants of one species. *C. simplex* has only been observed in deposits in which *C. euskirchensoides* is also present, but seems to have a more limited distribution than the latter.

Cingulatisporites paradoxus sp. nov.

(Pl. XVII, figs. 9-13; holotype, fig. 10)

Occurrence. South Australia—Robe Bore, 1,400-2,630 ft.; Cootabarlow Bore No. 2, at 581 ft. and 1,354 ft.; Tilcha Bore, at 460 ft. and 1,040 ft. Victoria—Dergholm Bore No. 1, at 532 ft.; Barongarook Creek; Birregurra Bore No. 1, 1,079-89 ft., 1,089-90 ft., and at 1,102 ft.; Gellibrand River (Devil's Kitchen); Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Barrabool Hills; Woodside Well No. 2, at 4,251 ft. New South Wales—Onepah Station Well.

Description. Spore alete, occasionally with faint indications of a tetrad-scar, flattened, subtriangular to almost circular in polar view, with convex sides, sometimes asymmetrical. Cingulum narrow, delicate and granular often partially, or wholly destroyed. Exine $1 \cdot 5$-3μ thick, 2-layered, scabrate to granulate usually, with a secondary pattern, at and around one of the poles, resulting from the development of

minute fractures which delimit one to several well-defined hexagonal areas; sometimes a distinct fovea with a rather irregular outline is formed by the further breakdown of the exine in this region.

Dimensions. Equatorial diameter 41-60μ, width of cingulum 1-3μ.

Comments. Cingulatisporites paradoxus is a readily recognizable form and, since it appears to be restricted to deposits of Albian-Aptian age, is likely to prove a useful index fossil.

As far as the morphology of *C. paradoxus* is concerned, some uncertainty exists regarding three of its main features: (1) The apparent absence of the tetrad-scar from the majority of examples (some 100 specimens at least have been examined) suggests that the alete condition is normal for this species. However, doubt in this connection has been created by the occasional appearance of what have been taken as faint laesurae. (2) The readily destructable nature of the equatorial flange, here interpreted as a cingulum (it is absent from a large proportion of examples), suggests the possibility that it may be of perinous nature. (3) The occasional occurrence of a fovea in the position usually occupied by the "secondary pattern" raises the question as to whether it is a natural or accidental opening and, if the former, whether it is developed on the distal surface, as in *Cirratriradites* Wilson and Coe or on the proximal surface as an opening mechanism in place of a normal tetrad-scar.

Genus **Lycospora** Schopf, Wilson and Bentall 1944

Lycospora mollis sp. nov.

(Pl. XVII, figs. 14-17; holotype, fig. 14)

Occurrence. South Australia—Robe Bore, at 3,860 ft.; Kopperamanna Bore, at 2,970 ft. Victoria—Birregurra Bore No. 1, 1,089-90 ft.; Apollo Bay; Barrabool Hills; Woodside Well No. 2, at 4,251 ft.; Wonthaggi State Coal Mine Area, locality (b).

Description. Spore radially symmetrical, trilete, globose, with a thin, narrow subequatorial ridge which is situated slightly nearer the distal than the proximal surface; the laesurae of the tetrad-scar are narrowly rimmed and extend almost to the marginal ridge. The exine is thin and granular.

Dimensions. Equatorial diameter 30-52μ; polar diameter 32-48μ.

Geological Range. Lower Cretaceous, Neocomian-Aptian and Albian.

Comments. Since all the species previously referred to the genus *Lycospora* have been of Carboniferous age and some, at least, have been isolated from cones of *Lepidostrobus* and *Lepidocarpon,* it was only after much consideration and hesitation that we decided to refer an Australian Upper Mesozoic dispersed form to this particular genus. Our main reasons for doing so were the close agreement that seems to exist between this form and the description and representation of *Lycospora* given by Schopf, Wilson and Bentall (1944, p. 54, Pl. III, fig. 19) and the consequent difficulty of providing a generic description that would be adequately distinct from that of *Lycospora.* [During the publication of this paper a Liasso-Rhaetic trilete spore has been referred to *Lysospora* (Harris, T. M., 1957. *Proc. Roy. Soc.* 147: 305).]

However, in view of the diverse differences in age and geographical location, no attempt has been made to compare *L. mollis* with any of the northern Paleozoic species.

L. mollis is almost invariably more or less deformed in glycerine jelly mounts and is better examined when resting freely in a 50 per cent solution of glycerine and water. The photographs shown in Pl. XVII, figs. 14-17 are of unmounted examples.

Infraturma ZONATI Potonié and Kremp 1954

Genus **Cirratriradites** Wilson and Coe 1940

Spores referable to the genus *Cirratriradites*, as redefined by Potonié and Kremp (1954), occur, generally in relatively small numbers, in a variety of Australian Upper Mesozoic deposits. Such spores have a relatively wide equatorial flange, and frequently a more or less well developed fovea on the distal surface. In some examples the distal wall is entire, but when this is the case the position in which the fovea is usually developed is indicated either by the greater density or more regular arrangement of the ornament at the distal pole.

Thus the present study shows that, in the Australian Mesozoic representatives of *Cirratriradites*, the distal opening is formed by the natural break-down of the exospore in a circumscribed preformed area, and that, as it is a developmental feature, neither its presence nor absence can be used for the characterization of individual species.

For this purpose dependence has had to be placed on the type of exospore sculpturing, a feature which, unfortunately, is considerably variable in these forms. Two types of sculptural element are distinguishable: (1) broad-based spinules; (2) coarse granules or verrucae. In both of these categories we have found and made allowance for considerable variation, but in doing so it is possible that spores of more than one species have been included in the three spore-species herein distinguished.

Cirratriradites is typically a late Paleozoic genus, most of the species having come from the Carboniferous of Europe and North America. An Australian Permian species *Cirratriradites splendens* has recently been described by Balme and Hennelly (1957). As far as we are aware no Mesozoic species of *Cirratriradites* have been previously recorded. One of our species shows a resemblance to *Aequitriradites inconspicuus* Delcourt and Sprumont from the Wealden of Belgium, the illustrated example of which shows a distinct opening in the exospore. However, M. Delcourt has kindly informed us that he regards the opening in this specimen as accidental and that the genus *Aequitriradites* is characterized by the absence of a fovea.

Cirratriradites verrucosus sp. nov.

(Pl. XVIII, figs. 2-6; holotype, figs. 5, 6)

Occurrence. South Australia—Robe Bore, 1,400-2,325 ft.; Cootabarlow Bore No. 2, at 581 ft. Victoria—Dergholm Bore No. 1, at 532 ft.; Birregurra Bore No. 1, at 1,089 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures, Bore No. 20, at 454 ft., Bore No. 21, at 327 ft.; Weipa Bore No. 1, 2,022-41 ft.

Description. Spore trilete, biconvex (flattened at the poles) with a subtriangular amb and with or without a fovea at the distal pole. The equatorial flange is moderately wide and rather thin and membranous with a dotted surface and sometimes a serrated margin. The laesurae of the tetrad-scar extend as narrow ridges from the outer edge of the flange along the proximal surface to end at varying distances from the pole. The exine is $2\text{-}3\mu$ thick and inconspicuously granulate to verrucate. In specimens in which the exine is entire, i.e. when a fovea has not been developed, a circular area in which the sculptural elements are strongly outlined and frequently radially arranged is evident at and around the distal pole. In those examples in which a fovea is present the break-down of the exine, to which the opening is due, has occurred invariably in this area, some of the verrucae of which usually remain around its margin.

Dimensions. Overall equatorial diameter 65-98μ; equatorial diameter of spore-body 48-70μ; flange 9-16μ wide.

Geological Range. Lower Cretaceous (Aptian-Albian).

Cirratriradites tilchaensis sp. nov.

(Pl. XVIII, figs. 7, 8; holotype, fig. 7)

Occurrence. South Australia—Tilcha Bore, at 460 ft.; Robe Bore, at 1,400 ft. and 3,860 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures, Bore No. 2, at 327 ft.

Description. Spore biconvex, amb broadly triangular to almost circular; zona almost smooth and generally rather thick; laesurae of tetrad-scar prominent but not extending to the pole. Exine about 2·5μ thick, distinctly verrucate in the vicinity of the distal pole where a fovea is frequently developed; otherwise faintly patterned.

Dimensions. Overall equatorial diameter 54-61μ; equatorial diameter spore 36-47μ; flange 5-7μ.

Geological Range. Lower Cretaceous, Neocomian-Aptian and Albian.

Comments. C. tilchaensis is similar in form to *C. verrucosus*, but differs in its smaller size and less clearly marked ornamentation.

Cirratriradites spinulosus sp. nov.

(Pl. XVIII, figs. 9-13; holotype, fig. 9. Pl. XIX, figs. 1-5)

Occurrence. South Australia—Robe Bore, 1,400-3,860 ft.; Tilcha Bore, at 460 ft.; Loxton Bore, at 1,410 ft. and 1,460 ft.; Cootabarlow Bore No. 2, at 581 ft.; Comaum Bore, at 708 ft. Victoria—Gellibrand River (Devil's Kitchen); Dergholm Bore No. 1, at 532 ft. and 582 ft.; Bore No. 2, at 329 ft.; Birregurra Bore No. 1, 1,089-102 ft.; Apollo Bay; Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft.; Wonthaggi State Coal Mine Area, localities (a), (b), (e^2); Tyers Bore No. 2, at 860 ft.; Berry Creek Bore No. 7, sample 68, Bore No. 18, at 278 ft.; Cape Paterson; Woodside Well No. 2, at 4,251 ft. and 6,402 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore No. 21, at 327 ft,. Bore No. 20, at 454 ft.

Description. Spore elliptical in equatorial view, subtriangular to subcircular in polar view, with or without a distal fovea. The equatorial flange has a granular and occasionally spiny surface and a serrated margin. The rays of the tetrad-scar are variable in extent and prominence and may be absent altogether; in some specimens they are only visible on the flange, whereas in others they can be traced to within a short distance of the proximal pole. The exine which is about 2-4μ, is covered with rather regularly and radially arranged short broadly-based spinules or straight-sided projections with rounded apices which are usually more widely dispersed towards the equator and more densely arranged on the distal than on the proximal surface. In surface view, the bases of the projections are either circular or polygonal in outline and a distinct range in size from *c.* 1-4μ.

A distal fovea is frequently present; when not developed the surface projections are usually more crowded or more regularly arranged over the distal pole.

Dimensions. Overall diameter 54-107μ; spore body 37-86μ; flange 5-15μ.

Geological Range. Lower Cretaceous, Neocomian-Aptian and Albian.

Comments. Cirratriradites spinulosus as defined above is a broad type, which probably includes spores of more than one plant species. However, its subdivision into smaller units has not been attempted owing to the occurrence of "intermediates" and the consequent difficulty of deciding exactly where the lines of separation should be drawn.

The chief variants are the size and shape of the ornament and, to a lesser extent, the size of the spores themselves. In some specimens, including the type, the exinous outgrowths are slender, small-based, straight-sided cones (Pl. XVIII, figs. 9, 10, 13) or finger-like processes; in others, especially those from the Apollo Bay deposit (Pl. XIX, fig. 3), the proximal portions are much enlarged and the apices merely minute medianly placed points.

As regards size, the examples occurring in the Gellibrand River deposit (Devil's Kitchen) are consistently larger than those of other deposits.

C. spinulosus is similar to the West Australian species *Zonalisporites acusus* Balme in form and in having a polar fovea. However, *Z. acusus* differs in the smaller size of the spore and the complete absence of a tetrad-scar.

Genus **Minerisporites** R. Potonié 1956

Minerisporites marginatus (Dijkstra)

Triletes marginatus Dijkstra 1951. *Med. Geol. Sticht. n.s.* 5: 13 (Pl. III, fig. 11).
Baldurnisporites marginatus (Dijkstra) Delcourt and Sprumont 1955. *Mem. Soc. Belg. Geol. n.s.* 4: 73 (Pl. IV, fig. 5).
Minerisporites marginatus (Dijkstra) Potonié 1956. *Geol. Jahrb.* 23: 68.

Since the first Australian record of *M. marginatus* (Dijkstra) by Cookson and Dettmann (1958), this species has been isolated from several additional localities. The main features of these examples have been constant, the only variation being the degree of prominence of the surface reticulum. The distribution of *M. marginatus* as at present known is as follows: South Australia—Robe Bore, at 1,400 ft., 1,780 ft., 3,325 ft. and 3,860 ft.; Loxton Bore, at 1,410 ft.; Comaum Bore, at 708 ft.; Cootabarlow Bore No. 2, at 1,465 ft. Victoria—Barongarook Creek; Dergholm Bore No. 2, at 329 ft.; Wonthaggi State Coal Mine Area, localities (b), (e^2). New South Wales—Onepah Station Well.

Geological Range. Lower Cretaceous, Necomian-Aptian and Albian.

Genus **Styxisporites** gen. nov.

Description. Microspore trilete with a membranous equatorial flange; tetrad-scar restricted to the spore-body, the laesurae tectate. Ornament in the form of spineous or blunt processes which are restricted to the distal surface.

The generic name refers to the Styx Coal Measures in Queensland, in certain shales of which one of the species is relatively abundant.

The spores comprising the genus *Styxisporites* are referred to the Infraturma Zonati rather than to the Infraturma Cingulati on account of the membranous nature of the equatorial flange (zona). However, no close agreement can be established with other microspore genera within this infraturma.

The two genera within the Zonati to which *Styxisporites* bears the closest resemblance are *Cirratriradites* Wilson and Coe and *Aequitriradites* Delcourt and Sprumont. However, *Styxisporites* differs from both these genera in the restriction of the tetrad-scar to the spore-body and the tectate nature of the laesurae and from *Cirratriradites* in the absence of ornamentation of the proximal surface.

Genotype. Styxisporites linearis.

Styxisporites linearis sp. nov.

(Pl. XIX, figs. 6-9; holotype, figs. 6, 7)

Occurrence. South Australia—Robe Bore, at 3,860 ft. Victoria—Wonthaggi localities (a), (b), (e^2).

Description. Spore trilete, subtriangular to subcircular; equatorial flange membranous 5-9μ wide with a serrated margin; tetrad-scar prominent, laesurae extending to the periphery of the spore-body. Exine thin, proximal surface smooth, distal surface ornamented by rather widely-spaced conical spines or more usually straight-sided blunt projections, which broaden slightly at the base.

Dimensions. Overall equatorial diameter 54-62μ; equatorial diameter of spore-body 43-49μ; length of exinous projections 7-9μ.

Geological Range. A rare type which appears to be restricted to deposits of Neocomian-Aptian age.

Styxisporites majus sp. nov.

(Pl. XIX, figs. 10-14; holotype, fig. 10)

Occurrence. Western Australia—Gearle Siltstone (lower part)—West Australian Petroleum Co.'s Rough Range Well No. 1, at 2,750 ft.; Moora Bore, 86-170 ft. South Australia—Tilcha Bore, at 460 ft. and 1,040 ft.; Cootabarlow Bore No. 2, at 581 ft.; Robe Bore, at 1,400 ft. Victoria—Birregurra Bore No. 1, at 1,089 ft. and 1,102 ft. New South Wales—Onepah Station Well. Queensland—Styx Coal Measures Bore No. 21, at 327 ft., Bore No. 20, at 450 ft.

Description. Spore trilete with a subtriangular to subcircular amb; the equatorial flange is relatively wide with a finely scabrate surface and serrated margin. The laesurae of the tetrad-scar are straight and extend to the periphery of the spore-body. The exine is about 1·5μ thick, smooth on the proximal surface and ornamented on the distal surface by rather widely-spaced conical spines or occasionally blunt straight-sided projections which usually arise from low ridges running parallel to the equatorial contour of the spore-body. Occasionally, as in the specimen shown in Pl. XIX, fig. 12, the ridges are more prominent and jagged and the spines reduced.

Dimensions. Overall equatorial diameter 60-79μ, equatorial diameter of spore-body 45-58μ, flange 9-16μ, length of spines 4-7μ.

Geological Range. Lower Cretaceous (Albian).

Comments. A few of the specimens from the Tilcha Bore and all those from Little's Shaft in the Bellarine Peninsula have smaller and more numerous spines than typical examples of *Styxisporites majus* (Pl. XIX, fig. 14). While it seems likely that they represent a distinct type too few of them have been recovered to justify specific separation.

S. majus differs from *S. linearis* in its larger size and in the presence of the low ridges from which the spines arise.

Spore Assemblages

As stated earlier, only a relatively small number of the trilete spore types present in the various deposits analysed have been described and classified. The lists included in this section give little idea of the microfloras as a whole and are included only as records and for comparative purposes.

A. Lower Cretaceous (Neocomian-Aptian)

1. South Australia
   (a) Robe Bore at 4,300 ft.
      Microspores—

Ceratosporites equalis
Dictyotosporites speciosus
Granulatisporites dailyi
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites circolumenus
Lycopodiumsporites austroclavatidites
Neoraistrickia truncatus
Pilosisporites notensis
Radiatisporites hughesi

(b) Robe Bore at 3,860 ft.

Microspores—

Apiculatisporis wonthaggiensis
Ceratosporites equalis
Cicatricosisporites australiensis
Cirratriradites spinulosus
Cirratriradites tilchaensis
Dictyotosporites speciosus
Dictyotosporites complex
Granulatisporites dailyi
Ischyosporites scaberis
Leptolepidites verrucatus
Lycospora mollis
Lycopodiumsporites austroclavatidites
Lycopodiumsporites circolumenus
Neoraistrickia truncatus
Osmundacidites comaumensis
Pilosisporites notensis
Radiatisporites hughesi
Styxisporites linearis

Megaspores—

Minerisporites marginatus

(c) Kopperamanna Bore at 2,970 ft.

Microspores—

Ceratosporites equalis
Cirratriradites spinulosus
Dictyotosporites speciosus
Dictyotosporites complex
Ischyosporites scaberis
Ischyosporites punctatus
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Lycopodiumsporites circolumenus
Lycospora mollis
Neoraistrickia truncatus
Osmundacidites comaumensis
Radiatisporites hughesi

(d) Cootabarlow Bore No. 2 at 1,465 ft.

Microspores—

Ceratosporites equalis
Dictyotosporites speciosus
Dictyotosporites complex
Ischyosporites punctatus
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Lycopodiumsporites circolumenus
Neoraistrickia truncatus
Osmundacidites comaumensis
Radiatisporites hughesi

Megaspores—

Minerisporites marginatus

2. Victoria

(a) Apollo Bay

Microspores—

Apiculatisporis wonthaggiensis
Ceratosporites equalis
Cicatricosisporites australiensis
Cirratriradites spinulosus
Dictyotosporites speciosus
Ischyosporites scaberis
Leptolepidites verrucatus
Lycospora mollis
Neoraistrickia truncatus
Osmundacidities comaumensis
Pilosisporites notensis

(b) San Remo

Microspores—

Ceratosporites equalis
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites circolumenus
Neoraistrickia truncatus
Osmundacidites comaumensis

(c) Cape Paterson

Microspores—

Ceratosporites equalis
Cicatricosiporites australiensis
Cirratriradites spinulosus
Dictyotosporites speciosus
Granulatisporites dailyi
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Neoraistrickia truncatus
Osmundacidites comaumensis
Pilosisporites notensis
Radiatisporites hughesi

(d) Wonthaggi State Coal Mine Area, localities (a), (b), (c^3), (e^2)

Microspores—

Apiculatisporis wonthaggiensis localities (c^3), (e^2) only
Ceratosporites equalis
Cicatricosisporites australiensis
Cirratriradites spinulosus localities (a), (b), (e^2) only
Dictyotosporites speciosus
Dictyotosporites complex
Granulatisporites dailyi
Ischyosporites punctatus locality (b) only
Ischyosporites scaberis
Kuylisporites lunaris localities (b), (e^2) only
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Lycopodiumsporites circolumenus localities (a), (b) only
Lycospora mollis locality (b) only
Neoraistrickia truncatus
Osmundacidites comaumensis
Pilosisporites notensis
Radiatisporites hughesi localities (a), (b), (c^3) only
Styxisporites linearis localities (a), (b), (e^2) only

Megaspores—

Minerisporites marginatus, localities (b), (e^2) only

(e) Whitelaw Railway Station

Microspores—

Apiculatisporis wonthaggiensis
Ceratosporites equalis
Cicatricosisporites australiensis
Dictyotosporites speciosus
Granulatisporites dailyi
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites austraclavatidites
Lycopodiumsporites circolumenus
Neoraistrickia truncatus
Osmundacidites comaumensis
Radiatisporites hughesi

(f) Berry Creek Bore at 278 ft., Bore 7, sample 18

Microspores—

Ceratosporites equalis
Cicatricosisporites australiensis
Cirratriradites spinulosus
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Lycopodiumsporites circolumenus
Neoraistrickia truncatus
Osmundacidites comaumensis
Pilosisporites notensis
Radiatisporites hughesi

(g) Tyers Bore No. 2 at 860 ft.

Microspores—

Ceratosporites equalis
Cicatricosisporites australiensis
Cirratriradites spinulosus
Dictyotosporites speciosus
Granulatisporites dailyi
Ischyosporites scaberis
Kuylisporites lunaris
Leptolepidites verrucatus
Neoraistrickia truncatus
Osmundacidites comaumensis

(h) Korumburra, shale above coal

Microspores—

Apiculatisporites wonthaggiensis
Ceratosporites equalis
Cicatricosisporites australiensis
Dictyotosporites speciosus
Granulatisporites dailyi
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Osmundacidites comaumensis
Pilosisporites notensis
Radiatisporites hughesi

B. Lower Cretaceous (Aptian and Albian)

1. South Australia

(a) Robe Bore

(i) 3,500 ft.

Microspores—

Ceratosporites equalis
Cicatricosporites australiensis
Cingulatisporites euskirchensoides
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Neoraistrickia truncatus
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis

(ii) 3,325 ft.

Microspores—

Apiculatisporis asymmetricus
Ceratosporites equalis
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cirratriradites spinulosus
Ischyosporites scaberis
Leptolepidites verrucatus
Neoraistrickia truncatus
Perotrilites striatus

Megaspores—

Minerisporites marginatus

(iii) 2,630 ft.

Microspores—

Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cingulatisporites simplex
Cirratriradites spinulosus
Ischyosporites scaberis
Lycopodiumsporites austroclavatidites
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis

Megaspores—

Balmeisporites holodictyus

(iv) 2,325 ft.

Microspores—

Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cirratriradites spinulosus
Cirratriradites verrucosus
Lycopodiumsporites austroclavatidites
Osmundacidites australiensis
Perotrilites striatus
Pilosisporites notensis

(v) 1,780 ft.

Microspores—

Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cirratriradites spinulosus
Cirratriradites verrucosus
Lycopodiumsporites austroclavatidites
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus
Minerisporites marginatus

(vi) 1,400 ft.

Microspores—

Apiculatisporis asymmetricus
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cingulatisporites simplex
Cirratriradites spinulosus
Cirratriradites verrucosus
Cirratriradites tilchaensis
Divisisporites euskirchenensis
Perotrilites striatus
Pilosisporites notensis
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Pyrobolospora hexapartita
Pyrobolospora reticulata
Pyrobolospora nuda
Balmeisporites holodictyus
Balmeisporites tridictyus
Minerisporites marginatus

(b) Tilcha Bore No. 1, 460-1,040 ft.

Microspores—

Apiculatisporis asymmetricus
460 ft.
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
1,040 ft.
Cingulatisporites paradoxus
Cingulatisporites simplex
1,040 ft.
Cirratriradites spinulosus
460 ft.
Cirratriradites tilchaensis
460 ft.
Djvisisporites euskirchenensis
460 ft.
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus
Balmeisporites tridictyus
Pyrobolospora hexapartita
460 ft.
Pyrobolospora nuda
460 ft.
Pyrobolospora reticulata
1,040 ft.

(c) Cootabarlow Bore No. 2

(i) 1,354 ft.

Microspores—

Ceratosporites equalis
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Dictyotosporites speciosus
Ischyosporites punctatus
Leptolepidites verrucatus
Lycopodiumsporites circolumenus
Lycopodiumsporites austroclavatidites
Neoraistrickia truncatus
Osmundacidites comaumensis
Pilosisporites notensis

(ii) 581 ft.

Microspores—

Apiculatisporis asymmetricus
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cirratriradites spinulosus
Cirratriradites verrucosus
Perotrilites striatus
Pilosisporites notensis
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus
Pyrobolospora reticulata

(d) Loxton Bore, 1,410-70 ft.

Microspores—

Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cirratriradites spinulosus
Ischyosporites punctatus
1,410 ft.
Ischyosporites scaberis
Leptolepidites verrucatus
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis

Megaspores—

Balmeisporites holodictyus
1,410 ft.
Minerisporites marginatus
1,410 ft.
Pyrobolospora reticulata
1,410 ft.

(e) Comaum Bore at 708 ft.

Microspores—

Ceratosporites equalis
Cicatricosisporites australiensis
Cirratriradites spinulosus
Dictyotosporites speciosus
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Neoraistrickia truncatus
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Radiatisporites hughesi

Megaspores—

Minerisporites marginatus

2. Victoria

(a) Dergholm Bore No. 1 at 532 ft.

Microspores—

Apiculatisporis asymmetricus
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cingulatisporites simplex
Cirratriradites spinulosus
Cirratriradites verrucosus
Ischyosporites scaberis
Leptolepidites verrucatus
Osmundacidites comaumensis
Perotrilites striatus

Megaspores—

Pyrobolospora reticulata

(b) Dergholm Bore No. 2 at 329 ft.

Microspores—

Apiculatisporis asymmetricus
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cirratriradites spinulosus
Leptolepidites verrucatus
Perotrilites striatus

Megaspores—

Minerisporites marginatus
Pyrobolospora reticulata

(c) Gellibrand River (Devil's Kitchen)

Microspores—

Apiculatisporis asymmetricus
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cirratriradites spinulosus
Perotrilites striatus
Trilobosporites trioreticulosus

(d) Birregurra Bore No. 1, 1,102-1079 ft.

Microspores—

Apiculatisporis asymmetricus 1,102-1,089 ft.
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides 1,089-1,102 ft.
Cingulatisporites paradoxus
Cingulatisporites simplex 1,102-1,089 ft.
Cirratriradites spinulosus 1,102-1,089 ft.
Divisisporites euskirchenensis 1,102 ft.
Leptolepidites verrucatus 1,102 ft.
Lycopodiumsporites austroclavatidites 1,102-1,089 ft.
Lycospora mollis 1,102-1,089 ft.
Osmundacidites comaumensis
Perotrilites striatus
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus 1,102-1,089 ft.

(e) Barongarook Creek

Microspores—

Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cingulatisporites simplex
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus
Minerisporites marginatus

(f) Barrabool Hills

Microspores—

Cicatricosisporites australiensis
Cingulatisporites paradoxus
Granulatisporites dailyi
Ischyosporites scaberis
Kuylisporites lunaris
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Lycospora mollis
Neoraistrickia truncatus
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus

(g) Little's Shaft, Bellarine Peninsula

Microspores—

Apiculatisporis asymmetricus
Ceratosporites equalis
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cingulatisporites simplex
Cirratriradites spinulosus
Kuylisporites lunaris
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
Lycopodiumsporites circolumenus
Neoraistrickia truncatus
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus
Pyrobolospora reticulata

(h) Woodside Well No. 2 at 4,251 ft. and 6,402 ft.

Microspores—

Apiculatisporis asymmetricus
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus 4,251 ft.
Cirratriradites spinulosus
Divisisporites euskirchenensis 4,251 ft.
Ischyosporites scaberis
Leptolepidites verrucatus
Lycopodiumsporites circolumenus 6,402 ft.
Lycospora mollis 4,251 ft.
Osmundacidites comaumensis
Perotrilites striatus 6,402 ft.
Pilosisporites notensis 4,251 ft.

3. New South Wales

Onepah Station Well

Microspores—

Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
Cingulatisporites paradoxus
Cirratriradites spinulosus
Cirratriradites verrucosus
Cirratriradites tilchaensis
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus
Minerisporites marginatus
Pyrobolospora hexapartita
Pyrobolospora reticulata

4. Queensland

Styx Coal Measures, Bore 21 at 327 ft., Bore 20 at 454 ft.

Microspores—

Ceratosporites equalis
327 ft.
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides
454 ft.
Cirratriradites spinulosus
Cirratriradites verrucosus
Cirratriradites tilchaensis
327 ft.
Ischyosporites scaberis
454 ft.
Leptolepidites verrucatus
327 ft.
Osmundacidites comaumensis
Perotrilites striatus
Pilosisporites notensis
Styxisporites majus
Trilobosporites trioreticulosus

Megaspores—

Balmeisporites holodictyus

5. Papua

Omati Bore, samples 1 and 2

Microspores—

Apiculatisporis asymmetricus (2)
Cicatricosisporites australiensis
Cingulatisporites euskirchensoides (2)
Leptolepidites verrucatus
Perotrilites striatus

Megaspores—

Balmeisporites holodictyus

Stratigraphical Implications

The samples from which the spores recorded above were recovered were portions of bore cores and outcrops of both fresh- and salt-water origin. The age of the salt-water deposits is known by the contained foraminifera, mollusca, and microplankton to be Lower Cretaceous; the freshwater sediments have been referred to the Jurassic on the basis of their macroscopic plant remains.

Although only a small proportion of the spores contained in both kinds of sediments have been considered in this contribution, it has been found that some of them are restricted to particular deposits while others are common to most, if not, all of them. Thus it seems possible to distinguish between "long" and "short-range" species and by means of the latter, to correlate the dated salt-water samples with the less reliably dated freshwater deposits, and to correlate individual freshwater deposits with one another.

The only continuous sequence avalable for study, has been the conformable succession of freshwater sediments intersected by the Robe Bore, 1,400-4,300 ft. In this section, a marked change in spore composition is noticeable above 3,500 ft., the sediments below this depth containing a different assemblage from that at or above it. It seems probable therefore that this change was coincident with a change in age which resulted in the passing out of older types and the incoming of newer ones in the vicinity of this level.

The Lower Cretaceous salt-water deposits comprise those from the Cootabarlow Bore at 581 ft. and 1,354 ft., the Tilcha Bore at 460 ft. and 1,040 ft., the Loxton Bore at 1,410 ft. and 1,470 ft., the Tooloombah Creek Bore No. 21 at 327 ft., and the Onepah Station Well. All these deposits are of Albian age, with the exception of the one at 1,354 ft. from the Cootabarlow Bore which is Aptian on the basis of foraminifera (N. H. Ludbrook, South Australian Department of Mines) and microplankton (Cookson and Eisenack 1958).

The short-range spores which occur in the Albian deposits are: *Divisisporites euskirchenensis, Cingulatisporites euskirchensoides* (Wealden in Belgium), *Cingulatisporites paradoxus, Cingulatisporites simplex, Trilobosporites trioreticulosus, Apiculatisporis asymmetricus, Perotrilites striatus, Pyrobolospora reticulata, Balmeisporites holodictyus.* A comparable association (Fig. 1) has been found in the upper section of the Robe Bore, 1,400-3,500 ft.; Dergholm Bore No. 1, at 532 ft. and 582 ft., Dergholm Bore No. 2, 329-31 ft.; Barongarook Creek; Birregurra Bore No. 1, 1,079-1,102 ft.; Gellibrand River (Devil's Kitchen); Barrabool Hills; Little's Shaft, Bellarine Peninsula, and Woodside Well No. 2, 4,257-6,402 ft. It appears therefore that the age of these deposits is Lower Cretaceous (approximately Albian) and not Lower Jurassic as was suggested for some of them by Medwell (1954a).

The spore association taken as typifying the lower portion of the Robe sequence represented by the samples taken at 3,860 ft. and 4,300 ft. comprises species such as *Granulatisporites dailyi, Apiculatisporis wonthaggiensis, Radiatisporites hughesi, Dictyotosporites speciosus, Dictyotosporites complex* and *Styxisporites majus,* none of which appear to be present in the Albian sediments. This difference in composition suggests that the age of the lower portion is almost certainly pre-Albian.

The number of spore types common to both the Albian and pre-Albian sediments of the Robe Bore for example, *Pilosisporites notensis, Ceratosporites equalis, Neoraistrickia truncatus, Lycospora mollis, Cirratriradites spinulosus, Cirratriradites verrucosus,* indicates that the older sediments approximate more closely to a Lower Cretaceous (pre-Albian) age than to the Jurassic age suggested for them by Ward (1917).

A comparable spore association to that found in the pre-Albian section of the Robe Bore occurs in deposits from the Wonthaggi State Coal Mine Area, and some of the same types occur in the deposit from the Kopperamanna Bore at 2,970 ft., and Cootabarlow Bore No. 2 at 1,465 ft., along with others that appear to be absent from the Robe sediments. The general agreement between these respective spore associations suggests that all are of approximately the same age, and that the Wonthaggi deposits are probably Lower Cretaceous (pre-Albian) rather than Lower-Middle Jurassic as suggested by Seward (1904) or Lower Jurassic as suggested by Medwell (1954a). Additional evidence for this younger age is provided by the occurrence of the megaspore *Minerisporites marginatus,* a type which occurs in the Wealden of the Netherlands Dijkstra (1951), and in England in the Ashdown Sands of the Wealden formation (Valanginian, Hughes 1958, p. 43).

When Seward compared the macroflora of the Wonthaggi Area with that of the Inferior Oolite of England and Rajmahal Hills of India, the age of the latter was considered to be Lower Jurassic. However, as the result of Dr. Spath's discovery of Neocomian ammonites in the Rajmahal Formation, a Lower Cretaceous (Neocomian) age has now been suggested for this formation (Arkell 1956).

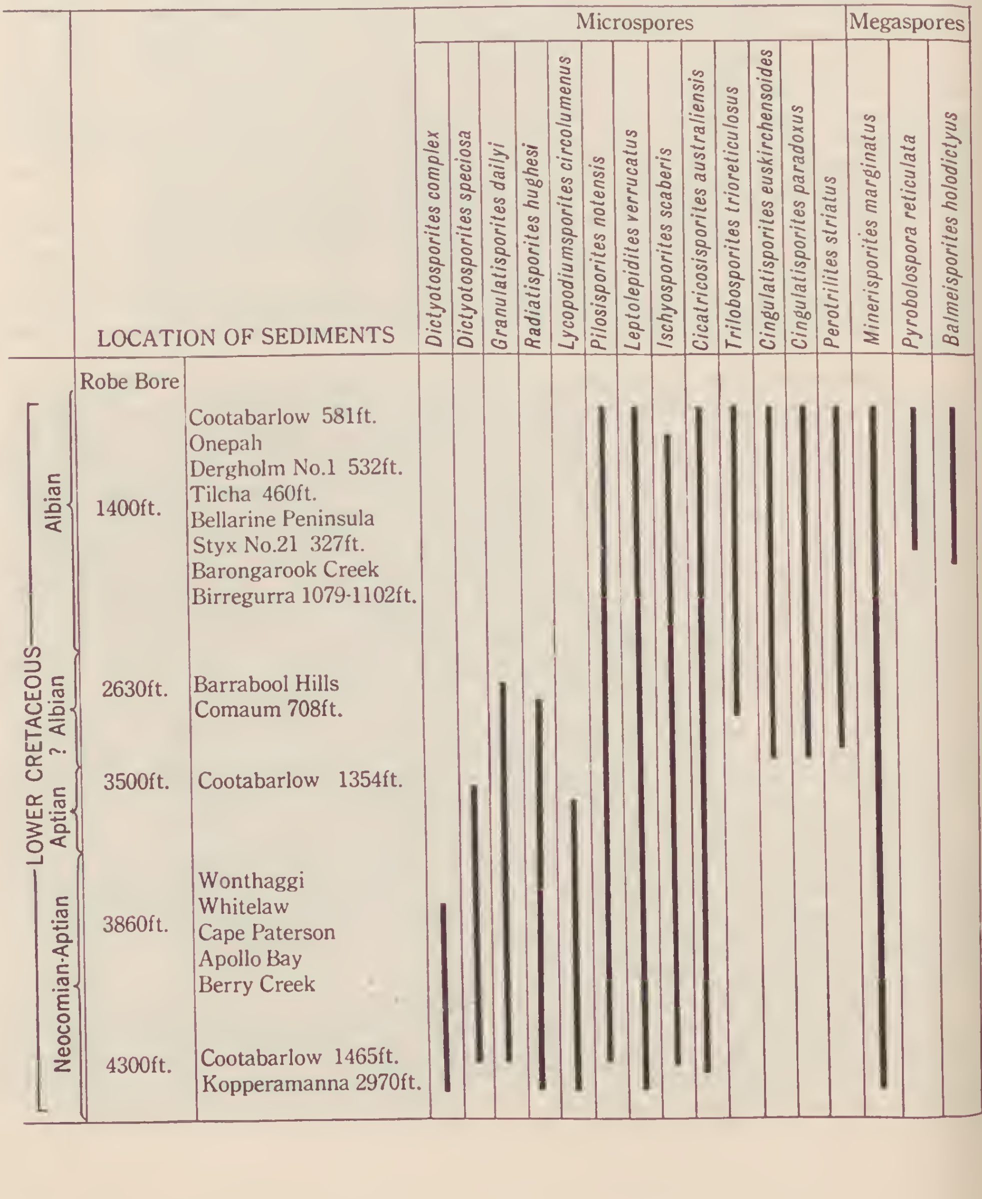
A similar age for the sediments from bores and outcrops at Wonthaggi, Cape Paterson, Berry Creek and Tyers River would conform with the spore content as as present known. Mr. B. E. Balme, who has investigated the Upper Mesozoic of Western Australia, has remarked upon the greater resemblance of the Wonthaggi microflora to that of the West Australian Lower Cretaceous than to the microfloras of the Upper Jurassic of the same area.

The South Australian deposits in the Cootabarlow No. 2 Bore at 1,465 ft. and in the Kopperamanna Bore at 2,970 ft., contain microflora assemblages comparable with those found in the Robe Bore, 4,300-3,860 ft., and in the Wonthaggi coals and associated shales. The sandstones, 3,000-2,810 ft., in the Kopperamanna Bore which undelie marine Cretaceous sediments were assigned by Whittle and Chebotarev

(1952, Fig. 2) to the Jurassic. More recently Woodard (1955, p. 15) suggested that "Interbedded coarse sandstones and subordinate clay shales underlying lower Cretaceous marine beds and regarded by Whittle (1952) as Jurassic, more probably represent the basal Cretaceous Blythesdale Sandstones".

There is thus some evidence for a Lower Cretaceous (pre-Albian) age for the Mesozoic deposits in the Wonthaggi State Coal Mine Area of Victoria and the lower sediments of the Robe Bore, 3,860-4,300 ft. These beds are tentatively referred to

TABLE 1



the Lower Cretaceous (Neocomian-Aptian). However, the possibility of an age older than Lower Cretaaceous, but younger than Lower Jurassic, must not be overlooked.

The sediments in the Comaum Bore, 651-708 ft., are of interest in containing a spore assemblage "intermediate" between typical Albian and Neocomian-Aptian microfloras. The presence of the microspore *Perotrilites striatus*, a species that has been invariably present in all the Albian deposits examined, leaves no doubt as to the Lower Cretaceous age of these deposits.

The spore assemblage of the Aptian deposit at 1,354 ft. in the Cootabarlow Bore No. 2, is closely similar to that of typical Albian deposits, but neither the microspore *Perotrilites striatus* nor the megaspores *Pyrobolospora reticulata*, and *Balmeisporites holodictyus* have been observed in it.

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Explanation of Plates

All the figures are from untouched negatives. Registered numbers in the palaeobotanical collection of the National Museum of Victoria are given.

PLATE XIV

Fig. 1.—*Divisisporites euskirchenensis* Thomson. Robe Bore, S.A., at 1,400 ft. × *c.* 580.

Figs. 2, 3.—*Granulatisporites dailyi* sp. nov. Proximal and distal surfaces of holotype. Wonthaggi State Coal Mine Area, Vic., locality (c^3). × *c.* 590. P17605.

Fig. 4.—*Granulatisporites dailyi*. Paratype. Comaum Bore, S.A., at 708 ft. × *c.* 560.

Fig. 5.—*Leptolepidites verrucatus* Couper. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c.* 650.

Fig. 6.—*Leptolepidites verrucatus*. Apollo Bay, Vic. × *c.* 650.

Figs. 7, 9, 10.—*Apiculatisporis wonthaggiensis* sp. nov. Paratypes. Wonthaggi State Coal Mine Area, Vic., locality (c^3). Fig. 7, × *c.* 840; Fig. 9, × *c.* 570; Fig. 10, × *c.* 620.

Fig. 8.—*Apiculatisporis wonthaggiensis*. Holotype. Wonthaggi State Coal Mine Area, Vic., locality (c^3). × *c.* 610. P17606.

Fig. 11.—*Apiculatisporis asymmetricus* sp. nov. Holotype. Birregurra Bore No. 1, Vic. at 1,102 ft. × *c.* 590. P17607.

Fig. 12.—*Apiculatisporis asymmetricus*. Paratype. Dergholm Bore No. 1, Vic. at 532 ft. × *c.* 590.

Fig. 13.—*Osmundacidites comaumensus* (Cookson). Holotype. Comaum Bore, S.A. at 674 ft. × *c.* 550. P17608.

Fig. 14.—*Neoraistrickia truncatus* (Cookson). Holotype. Comaum Bore, S.A. at 708 ft. × *c* 600.

Fig. 15.—*Neoraistrickia truncatus*. Paratype. Comaum Bore, S.A. at 708 ft. × *c.* 620.

Fig. 16.—*Neoraistrickia truncatus*. Showing the small processes of the proximal surface. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c.* 870.

Figs. 17-19.—*Ceratosporites equalis* sp. nov. Proximal, sectional and distal views of holotype. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c.* 640. P17609.

Fig. 20.—*Ceratosporites equalis*. Lateral view. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c.* 580.

Fig. 21.—*Kuylisporites lunaris*. Paratype. Wonthaggi State Coal Mine Area, Vic., locality (e^2). × *c.* 550.

Figs. 22, 23.—*Kuylisporites lunaris* sp. nov. Holotype. Wonthaggi State Coal Mine Area, Vic., locality (e^2). Fig. 22, × *c.* 650; Fig. 23, × *c.* 850. P17610.

Plate XV

Fig. 1.—*Pilosisporites notensis* sp. nov. Holotype. Robe Bore, S.A. at 3,680 ft. × *c.* 570. P17611.

Fig. 2.—*Pilosisporites notensis*. Paratype. Robe Bore, S.A. at 3,860 ft. × *c.* 570.

Fig. 3.—*Pilosisporites notensis* in equatorial view. Robe Bore, S.A. at 3,860 ft. × *c.* 570.

Figs. 4, 5.—*Radiatisporites hughesi* sp. nov. Wonthaggi State Coal Mine Area, Vic., locality (c^3). Fig. 4, Holotype, × *c.* 580, P17612; Fig. 5, Paratype, × *c.* 700.

Fig. 6.—*Radiatisporites hughesi*. Distal surface of a paratype. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c.* 580.

Fig. 7.—*Ischyosporites scaberis* sp. nov. Paratype in sub-polar view. Robe Bore at 3,860 ft. × *c.* 570.

Figs. 8, 9.—*Ischyosporites scaberis*. Proximal and distal surfaces of holotype. Robe Bore at 3,860 ft. × *c.* 570. P17613.

Figs. 10, 11.—*Lycopodiumsporites circolumenus* sp. nov. Proximal and distal surfaces of holotype. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c.* 560. P17614.

Fig. 12.—*Lycopodiumsporites austroclavatidites* (Cookson). Holotype. Comaum Bore, S.A. at 674 ft. × *c.* 560. P17615.

Fig. 13.—*Cicatricosisporites australiensis* (Cookson). Holotype. Comaum Bore, S.A. at 674 ft. × *c.* 580. P17616.

Fig. 14.—*Cicatricosisporites australiensis*. Berry Creek, Vic., Bore No. 18 at 278 ft. × *c.* 640.

Plate XVI

Figs. 1, 4.—*Ischyosporites punctatus* sp. nov. Kopperamanna Bore, S.A. at 2,970 ft. Fig. 1, proximal surface of holotype. × *c.* 620. P17617; Fig. 4, proximal surface of a paratype in oblique view. × *c.* 600.

Fig. 2.—*Ischyosporites punctatus*. Paratype. Cootabarlow Bore No. 2, S.A. at 1,354 ft. × *c.* 600.

Fig. 3.—*Ischyosporites punctatus*. Loxton Bore, S.A. at 1,410 ft. × *c.* 600.

Fig. 5.—*Dictyotosporites speciosus* sp. nov. Holotype. Wonthaggi State Coal Mine Area, Vic., locality (e^2). × *c.* 850. P17618.

Fig. 6.—*Dictyotosporites speciosus*. Paratype. Robe Bore, S.A. at 3,860 ft. × *c.* 600.

Fig. 7.—*Dictyotosporites speciosus*. High focus of distal surface showing double reticulum. Robe Bore, S.A. at 3,860 ft. × *c.* 1,300.

Figs. 8, 9, 10.—*Dictyotosporites speciosus*. Optical sections of exine of examples from the Robe Bore, S.A. × *c.* 1,300.

Fig. 11.—*Dictyotosporites complex* sp. nov. Holotype. Robe Bore, S.A. at 3,870 ft. × *c.* 610. P17619.

Figs. 12, 13.—*Dictyotosporites* cf. *complex*. Robe Bore, S.A. Fig. 12, × *c.* 600; Fig. 13, a more highly magnified surface view of the specimen in fig. 12, showing the reticulum and the supporting threads which are represented by small white or black "dots" at the angles of the mesh. × *c.* 1,300.

Fig. 14.—*Dictyotosporites* cf. *complex*. Wonthaggi State Coal Mine Area, locality (b). × *c.* 600.

Figs. 15, 16.—*Dictyotosporites complex*. Kopperamanna Bore, S.A. Fig. 15, exine after removal of outer reticulum showing thread-like "primary" processes. × *c.* 1,300; Fig. 16, one of of the "primary" processes showing bifurcation. × *c.* 1,800.

Fig. 17.—*Perotrilites striatus* Cookson and Dettmann. Robe Bore, S.A. × *c.* 630.

Fig. 18.—*Perotrilites striatus*. Styx Coal Measures Qsld., Bore No. 21 at 327 ft. × *c.* 600.

Plate XVII

Figs. 1, 2.—*Trilobosporites trioreticulosus* sp. nov. Paratypes. Cootabarlow No. 2 Bore, S.A. at 581 ft. Fig. 1, × *c.* 590; Fig. 2, × *c.* 530.

Fig. 3.—*Trilobosporites trioreticulosus*. Holotype. Styx Coal Measures, Qsld., Bore No. 21 at 327 ft. × *c.* 590. P17620.

Figs. 4-6.—*Cingulatisporites euskirchensoides* Delcourt and Sprumont. Fig. 4, Birregurra Bore No. 1, Vic. at 1,102 ft. × *c.* 640; Fig. 5, Robe Bore, S.A. at 2,630 ft. × *c.* 540; Fig. 6, Styx Coal Measures Bore No. 21, Qsld. at 327 ft. × *c.* 540.

Fig. 7.—*Cingulatisporites simplex* sp. nov. Paratype. Birregurra Bore No. 1, Vic., 1,089-90 ft. × *c.* 540.

Fig. 8.—*Cingulatisporites simplex*. Holotype. Birregurra Bore No. 1, Vic. at 1,102 ft. × *c*. 600. P17621.

Figs. 9, 11.—*Cingulatisporites paradoxus* sp. nov. Paratypes. Birregurra Bore No. 1, Vic. 1,089-90 ft. × *c*. 600; Fig. 9, showing faint indications of tetrad-scar.

Fig. 10.—*Cingulatisporites paradoxus*. Holotype. Birregurra Bore No. 1, Vic. 1,089-90 ft. × *c*. 600. P17622.

Figs. 12, 13.—*Cingulatisporites paradoxus*. Paratypes. Robe Bore, S.A. at 2,630 ft. × *c*. 570; Fig. 12, showing fovea.

Fig. 14.—*Lycospora mollis* sp. nov. Holotype. Birregurra Bore No. 1, Vic., 1,089-90 ft. × *c*. 600. P17623.

Figs. 15-17.—*Lycospora mollis*. Paratypes. Barrabool Hills, Vic. Fig. 15, spore in oblique view. × *c*. 600; Figs. 16, 17, high and low focus of spore in equatorial view. × c. 400.

Plate XVIII

Fig. 1.—*Dictyotosporites complex*. Cootabarlow Bore No. 2, S.A. at 1,465 ft. × *c*. 590.

Figs. 2, 3.—*Cirratriradites verrucosus* sp. nov. Polar views of proximal and distal surfaces of a paratype. Tilcha Bore, S.A. at 1,040 ft. × *c*. 560.

Fig. 4.—*Cirratriradites verrucosus*. A paratype with large distal fovea. Weipa Bore No. 1, North Qsld. at 2,022 ft. × *c*. 560.

Figs. 5, 6.—*Cirratriradites verrucosus*. Holotype in proximal and distal views. × *c*. 560. P17624.

Fig. 7.—*Cirratriradites tilchaensis* sp. nov. Distal view of holotype. Tilcha Bore, S.A. at 460 ft. × *c*. 560. P17625.

Fig. 8.—*Cirratriradites tilchaensis*. Distal view of a paratype. Tilcha Bore, S.A. at 1,040 ft. × *c*. 560.

Fig. 9.—*Cirratriradites spinulosus sp. nov*. Optical section of holotype. Wonthaggi State Coal Mine Area, Vic., locality (e^2). × *c*. 590. P17632.

Figs. 10, 13.—*Cirratriradites spinulosus*. Fig. 10, distal surface of spore from Gellibrand River, Vic. (Devil's Kitchen), × *c*. 570; Fig. 13, Robe Bore, S.A. at 3,325 ft. × *c*. 580.

Figs. 11, 12.—*Cirratriradites spinulosus*. Proximal and distal surfaces of a paratype. Onepah Station Well, N.S.W. × *c*. 570.

Plate XIX

Figs. 1, 2.—*Cirratriradites spinulosus*. Gellibrand River (Devil's Kitchen), Vic. Fig. 1, distal surface, × *c*. 560; Fig. 2, exine of proximal polar area showing variability in size and shape of spinule-bases, × *c*. 560, exceptionally large.

Fig. 3.—*Cirratriradites spinulosus*. Showing much enlarged spinule-bases, Apollo Bay, Vic. × *c*. 570.

Figs. 4, 5.—*Cirratriradites spinulosus*. Fig. 4, Tyers Bore No. 2, Vic. at 860 ft. × *c*. 570; Fig. 5, Cootabarlow Bore No. 2, S.A. at 581 ft. × *c*. 560.

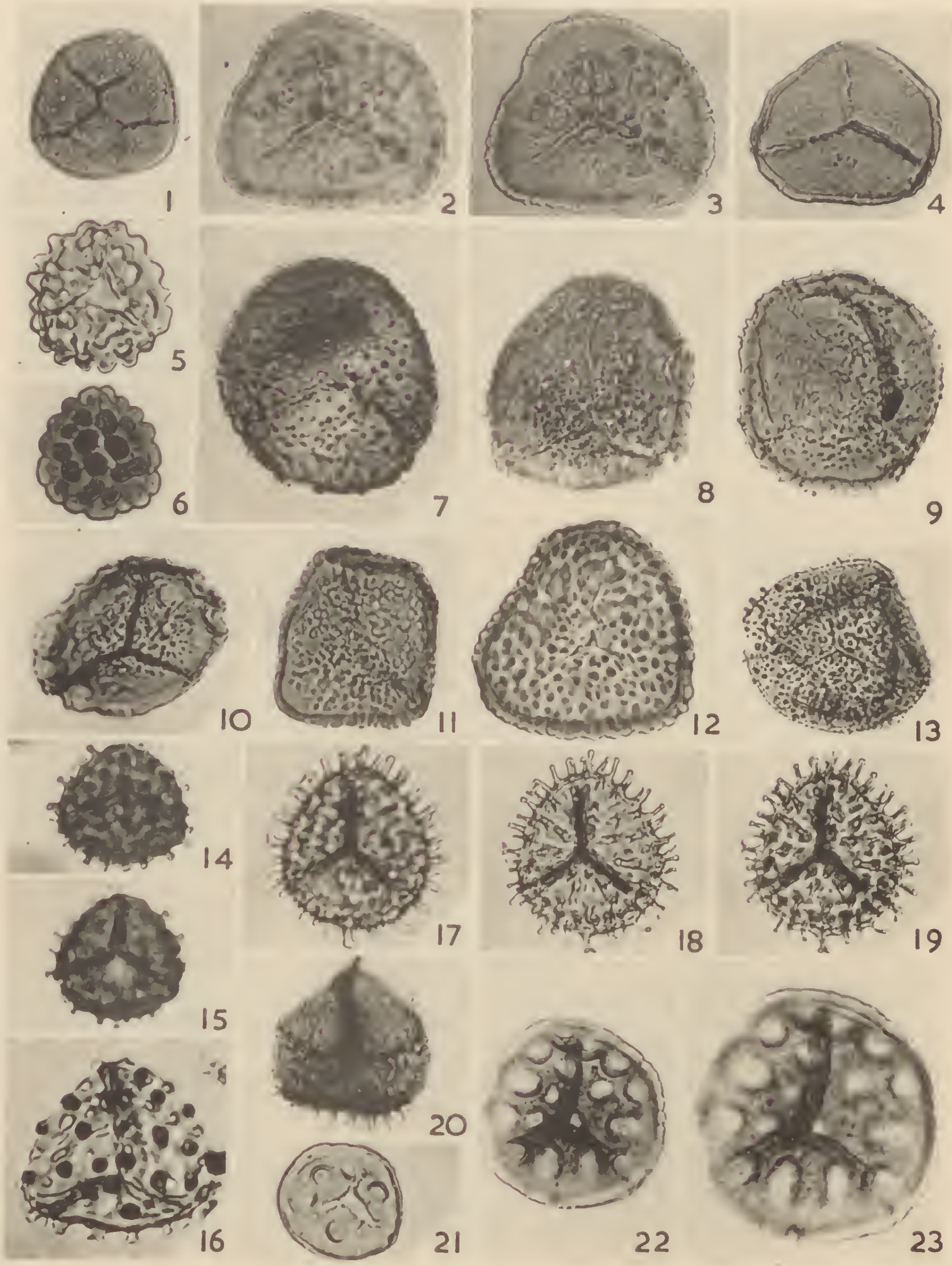
Figs. 6, 7.—*Styxisporites linearis* sp. nov. Distal view and optical section of holotype. Wonthaggi State Coal Mine Area, locality (e^2). × *c*. 570. P17630.

Figs. 8, 9.—*Styxisporites linearis*. Proximal and distal surface of a paratype. Wonthaggi State Coal Mine Area, Vic., locality (b). × *c*. 600.

Fig. 10.—*Styxisporites majus* sp. nov. Distal surface of holotype. Tilcha Bore, S.A. at 460 ft. × *c*. 580. P17625.

Figs. 11, 12.—*Styxisporites majus*. Paratypes. Styx Coal Measures, Qsld., Bore No. 21 at 327 ft. × *c*. 560.

Figs. 13, 14.—*Styxisporites majus*. Fig. 13, examples showing short and stumpy as well as pointed projections from Moora Bore, W.A., 86-170 ft. × *c*. 560; Fig. 14, example with ornament in the form of short and slender spinules. Bellarine Peninsula, Little's Shaft No. 2, 38-47 ft. × *c*. 560.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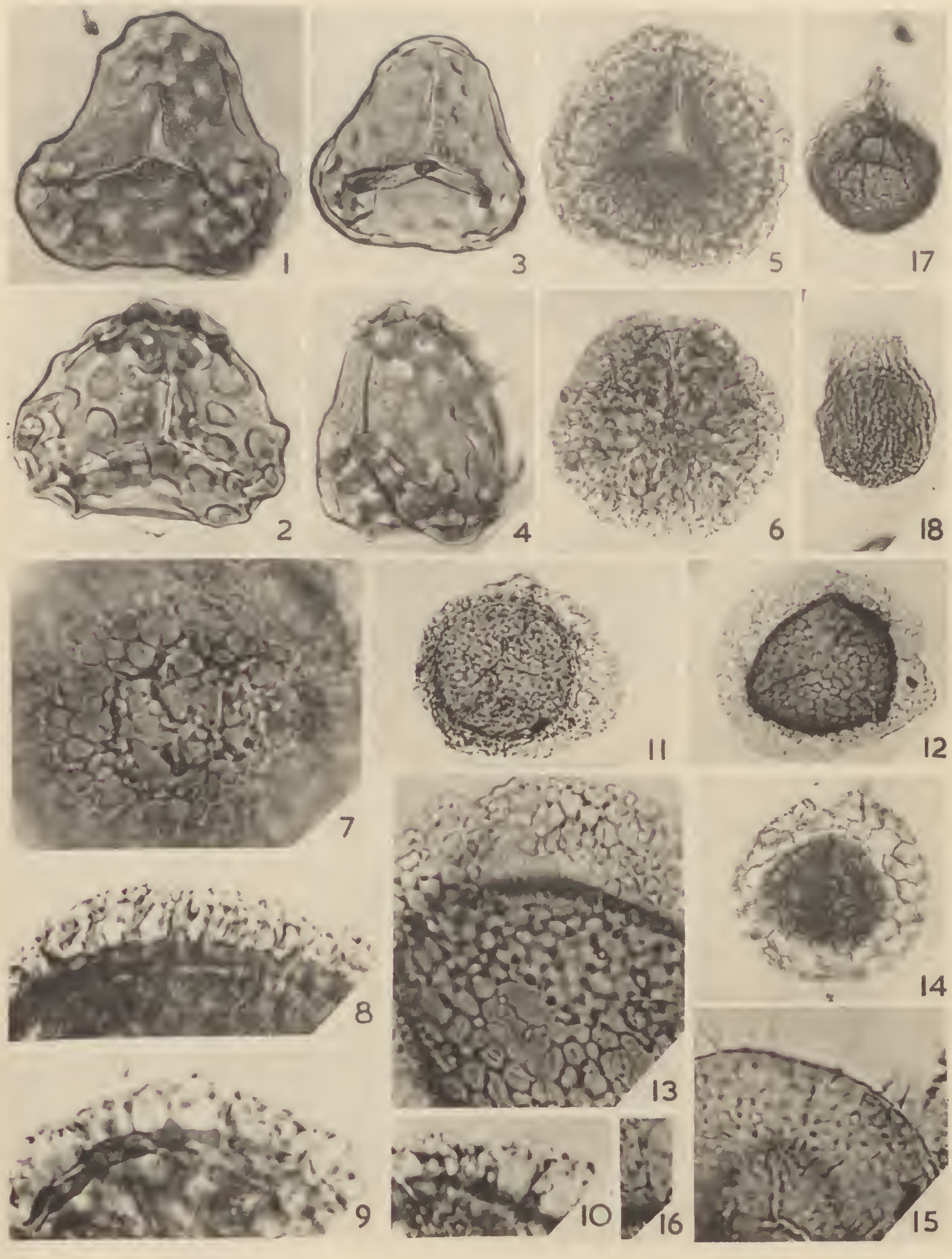
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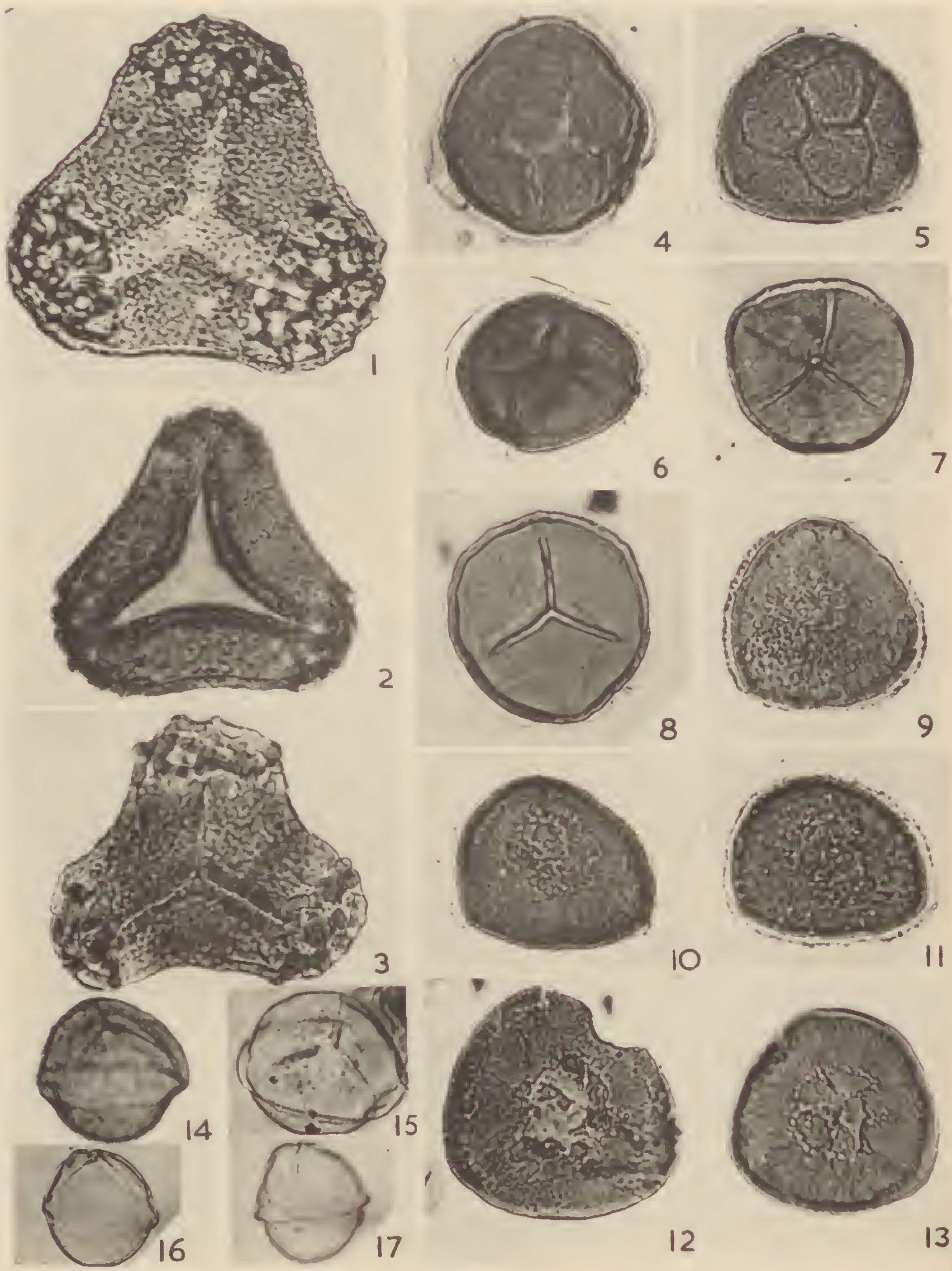
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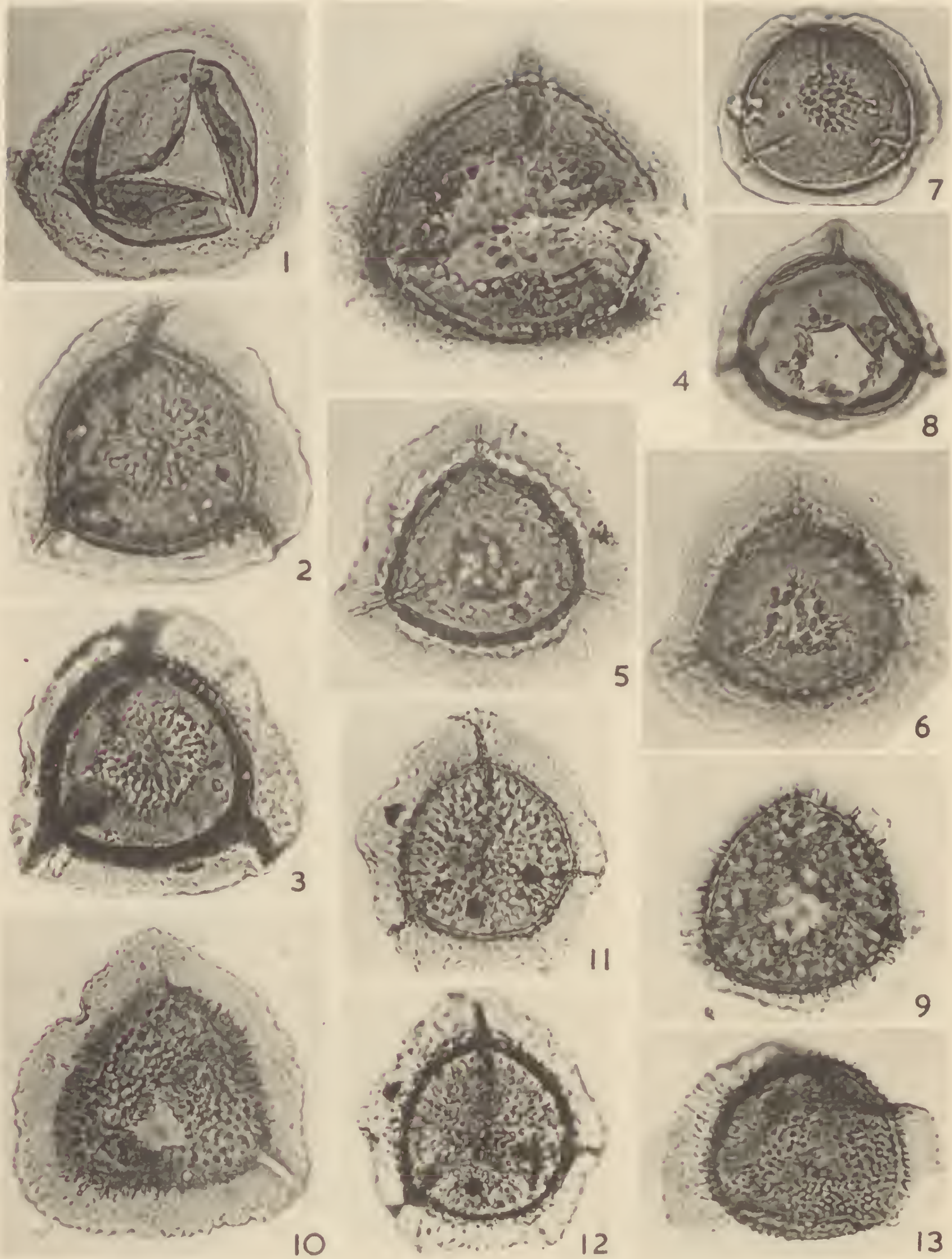
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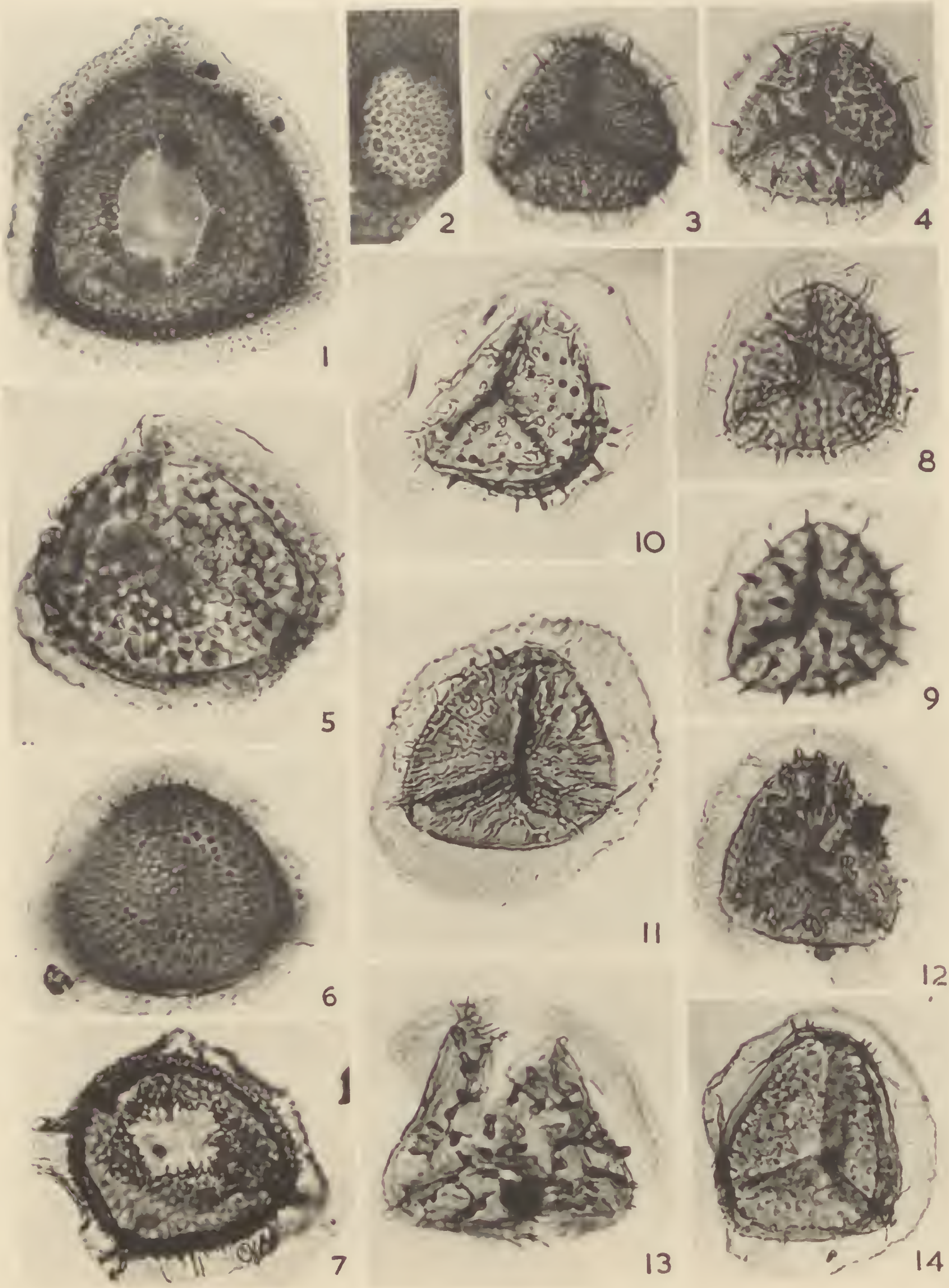

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FOSSIL WOOD FROM VICTORIAN BROWN COAL

By R. T. Patton, D.Sc., D.I.C., M.F., F.R.H.S.

[Read 12 December 1957]

Abstract

The wood of five species of gymnosperms and two species of angiosperms from Victorian brown coals is described. The genera concerned are *Agathis, Podocarpoxylon, Phyllocladoxylon, Casuarina* and *Banksia*. Problems associated with the formation of the brown coal are discussed.

Introduction

The brown coal deposits of Victoria, which, according to Thomas and Baragwanath (1949), are mainly of Oligocene age but may extend into the Eocene, contain large amounts of fossil wood in an excellent state of preservation. There has been very little research in connection with this wood, the only previous studies being those of Nobes (1922), which dealt with coniferous wood from Yallourn and also from Moorlands in South Australia. The present paper is concerned with material from the brown coal at Yallourn and Bacchus Marsh, and an account is given of the fossil wood of four new species of conifers and two new species of angiosperms. Details are also given of the wood of another coniferous species which had previously only been recorded from Tertiary deposits at Ballarat.

Description of Species

Before describing the woods found in the brown coal, it is necessary to point out that, particularly in the coniferous wood, abnormalities are present in some of the material examined. This point is important because some of the features shown by this type of material could be regarded as characteristic of the normal wood of the species concerned.

The well-known features of so-called compression wood in conifers (Pillow and Luxford 1937, Münch 1937-8, Jaccard 1938) include relatively indistinct growth rings, abundant intercellular spaces in the spring wood, spring wood tracheids rounded in cross-section, rather thick-walled with spiral checks on the secondary walls, and bordered pits showing extended, slit-like orifices. All these features are shown in the material described here as *Podocarpoxylon australe* and *P. minor*, and there is no doubt that the specimens represent compression wood. The rounded tracheids with spiral checks on the walls and the slit-like orifices of the bordered pits are shown particularly clearly in *P. australe* (Pl. XX, figs. 3, 8, 11, 12), and are almost as pronounced in *P. minor*.

From the above, it can be seen that the descriptions of the shape of the tracheids in cross-section, the thickness of the tracheid walls and the distinctness of the annual rings of both *P. australe* and *P. minor* are not necessarily valid for normal wood. However, the annual rings of both species are absent or so feebly developed that it is most unlikely that they were well defined in the normal wood. Descriptions of the bordered pits are considered to be accurate because it was possible to find occasional normal pits in the compression wood.

Groups of distorted tracheids, in which the lumen is reduced or obliterated, occur in much of the coniferous material examined (see P. XX, fig. 4; Pl. XXII, fig. 17). These distorted tracheids usually form tangential bands (presumably rings in many cases) in which the medullary rays are frequently displaced and distorted (Pl. XX, figs. 2, 5), but they may also form radial bands, and the latter type is the only one noted in *Agathis resinifera*. In *Podocarpoxylon australe*, the tangential bands are sometimes associated with clefts filled with very large, thick-walled parenchyma (Pl. XX, figs. 2, 4), and in *P. minor* there are more or less spherical cavities bounded by distorted tracheids. Tangential bands of distorted tracheids and distorted medullary rays were observed in all the species of *Podocarpoxylon* described below, but were not seen in the other coniferous woods.

These bands of distorted tracheids and the associated phenomena are such obvious abnormalities that they are unlikely to affect the accuracy of descriptions of the fossil woods, but they are so conspicuous that they are worthy of note. In many cases, these abnormalities resemble frost rings (Rhoads 1923, Day and Peace 1934). However, Day and Peace showed that abnormalities which are indistinguishable from certain types of frost ring can be produced experimentally by watering trees insufficiently or by immersing their roots in a tank of water, and Tubeuf (1906) noted that similar rings can be produced by lightning. Frost rings frequently show a very large amount of wood parenchyma, and it is of interest to note that this is not present in either the rings in the fossil wood or in those induced by changes in the water relationships. The collapsed tracheids which may occur when green timber of recent trees is dried (Greenhill 1936, Tiemann 1941, Anon. 1942) are similar to some of the abnormal tissue in the fossils, but these collapsed tracheids are not, of course, associated with enlarged parenchyma cells. It may be noted that collapse of this type is very prevalent in Australian timbers, and that wood from trees grown in swampy areas is particularly likely to show it. It is obvious that, until more material of a similar type is obtained, it is not possible to determine the real cause of the abnormal tissue in the fossils, and in fact the cause of the abnormality may not be the same in each case. As the areas of distorted tracheids are discontinuous, it is unlikely that they are the result of compression by the overlying layers, which would probably affect the whole specimen. Specimens in which all the cells are distorted and most of the structural details obliterated have in fact been found.

In *Agathis resinifera*, the secondary walls of many of the tracheids have disintegrated, so that transverse sections show the primary wall surrounding a uniform granular mass without a lumen (Pl. XXII, figs. 13, 17). All stages between cells with normal walls and those in which the secondary wall has become completely indistinguishable can be seen in the sections. The cause of this disintegration is not known.

Finally, it may be noted that the wood described as *Banksia fossilis* has been subjected to fungal attack prior to its preservation in the brown coal. The medullary rays seem to have been the main tissue infected by the fungus, and the ray cells are often filled with hyphae and collapsed so that the lumen is scarcely visible (Pl. XXIII, figs. 11, 14, 15). In contrast to all the other material examined, this wood was extremely difficult to cut, as the sections broke up into small fragments as soon as they were prepared. For this reason, it has been impossible to obtain a complete description of all parts of the wood or a satisfactory estimate of the size of the medullary rays, etc., or to take a full set of photographs. However, it is considered that the description and illustrations are adequate for the subsequent recognition of the species.

In the descriptions which follow each average measurement cited is the mean of 100 measurements.

GYMNOSPERMAE

Araucariaceae

Agathis resinifera sp. nov.

(Pl. XXII, figs. 12-17; Pl. XXIII, figs. 1-7)

Transverse Section. Annual rings indistinct or absent. Tracheids rounded, average tangential diameter $30\cdot5\mu$ (15-48μ), walls 2-8μ thick, primary and secondary walls distinct. Resin plates present in tracheids adjoining medullary rays; the walls of these parts of the tracheids are thicker than those further from the rays. Resinous wood parenchyma present but sparse. Medullary rays uniseriate, resinous.

Radial Longitudinal Section. Bordered pits on the radial walls of the tracheids sparse to abundant, usually 1-, 2- or 3-seriate, rarely partially 4-seriate. Pits alternate when multiseriate. Average diameter of pits of the spring wood $11\cdot5\mu$ (7-13μ). Pits circular to hexagonal, pores small, short, oval to circular, oblique; the pores on the opposite sides of an individual pit may be at an angle to one another. Resinous parenchyma conspicuous, tranverse walls thin, smooth, pits small, diameter about 5μ.

Medullary rays parenchymatous, cells frequently irregular in shape. Horizontal and end walls thin (about 1μ), more or less smooth, end walls without indentures. Cross-field pits usually oval to circular with a narrow oblique aperture which nearly reaches the border at either end, but the pore may be short and almost circular or else slit-like and extending to the border at either end. Both axes of the pits range from 5-13μ in length. Usual number of pits per cross-field 3-7, average 5, range 1-12. Pits usually in vertical rows, closely placed but rarely flattened at the zone of contact.

Tangential Longitudinal Section. Bordered pits on the tangential walls of the tracheids occasionally present. Medullary rays uniseriate, 1-12 cells high (average nearly 4), usually 2-6. Cells oval to more or less rectangular, average tangential diameter 16μ (12-28μ), average height 41μ (25-71μ). Resin plates in the parts of the tracheids adjacent to the medullary rays conspicuous, up to 200μ in height and with concave ends.

Locality. Yallourn.

Comments. Nobes (1922) described *Dadoxylon* sp. from the Yallourn brown coal, and it is possible that her material represents the same species as that described above. However, her description is incomplete, and could probably apply to several species of either *Agathis* or *Araucaria*, both of which are known to occur in the Yallourn brown coal (Cookson and Duigan 1951). Furthermore, Nobes's illustration shows simple cross-field pits with vertically orientated pores, and this type of pitting has not been observed in *Agathis resinifera*. Greguss (1955) uses the orientation of the pores in the cross-field pits for the separation of some of the living species of *Agathis* and *Araucaria*, and hence it seems probable that this feature is sufficient to separate Nobes's *Dadoxylon* sp. from *Agathis resinifera*.

Nobes made no mention of resin plates in those parts of the tracheids which are adjacent to the medullary rays. This feature, which is very conspicuous in *Agathis resinifera*, appears to be the same as that described for the wood of various living and fossil species of the family Araucariaceae by Penhallow (1907), Thomson (1914), Stopes (1914) and Edwards (1921). The work of Stopes and Edwards refers to fossil species from the Australasian region, and hence these merit further attention. Stopes described *Araucarioxylon novae zeelandii* from a Cretaceous

deposit in New Zealand and, although this wood is rather similar to that of *Agathis resinifera*, there are a number of differences which, together with the difference in the age and geographical location of the two woods, are sufficient to separate them. Edwards gave a fuller account of the wood from the Tertiary of Kerguelen Island which was originally described by Seward (1919) as *Dadoxylon kerguelense*. The wood of *D. kerguelense* is very similar to that of *Agathis resinifera* but, in view of the great distance between the localities at which they were found, it seems advisable to regard them as separate species, at least until more is known of the significance of the small differences in structure which do exist between them.

The difficulties of separating the wood of *Agathis* from that of *Araucaria* are well known (Patton 1928a, Phillips 1941, Greguss 1955). However, in the present case, it was possible to identify the fossil as *Agathis* because of the nature of the bark. This identification is supported by the fact that many characters known to be more common in *Agathis* than in *Araucaria* are present in the fossil. In the earlier paper (Patton 1928a), it was pointed out by the present author that resin in the tracheids and medullary rays is more common in *Agathis* than in *Araucaria*, and resin is abundant in these regions of the fossil. Phillips (1941) believes that 4-seriate rows of bordered pits on the tracheid walls occur in *Agathis* and not in *Araucaria*, and again the fossil shows this character. Greguss (1955) states that wood parenchyma was found only in *Agathis*; there is wood parenchyma in the fossil, but the value of this distinction is uncertain, as Greguss suggests later that there may be very sparse wood parenchyma in *Araucaria*.

It is possible that the fossil wood described above may come from the same species as the one which provided the leaves and cones described by Cookson and Duigan (1951) as *Agathis yallournensis* but, in the absence of any direct evidence of a connection between them, *A. resinifera* must be regarded at present as a separate species. This conclusion is supported by the fact that Cookson and Duigan found a second species of *Agathis* in the brown coal at Bacchus Marsh, and this species may have extended to Yallourn.

Podocarpaceae

Podocarpoxylon australe (F.v.M.) Kräusel

(Pl. XX, figs. 1-12)

Transverse Section. Annual rings indistinct or absent. Tracheids irregular in outline, circular to polygonal in shape, average tangential diameter 32μ (10-50μ). Tracheid walls thick (4-8μ), primary and secondary walls distinct. Wood parenchyma diffuse, resinous and rather sparse. Medullary rays uniseriate, resinous.

Radial Longitudinal Section. Bordered pits on the radial walls of the tracheids rather sparse, uniseriate, average diameter in the spring wood 14μ (12-18μ). Pits more or less circular, apertures small, short, oval, oblique; the pores on the opposite sides of an individual pit may be at an angle to one another. Resinous wood parenchyma conspicuous, tranverse walls more or less smooth to nodular, pits small (longest diameter about 6μ), oval, apertures oblique.

Medullary rays parenchymatous. Horizontal and end walls thin (*c.* 1-$1{\cdot}5\mu$) and more or less smooth, end walls without indentures. Cross-field pits oval, longer diameter 5-12μ (average 8μ), shorter diameter (which coincides with the long axis of the pore) 4-9μ, average $5{\cdot}5\mu$. Pores of the cross-field pits rather narrow, oblique, usually reaching the border at either end. Number of pits per cross-field usually 1, occasionally 2 or 3; when two pits are present, their position varies from vertical to horizontal.

TANGENTIAL LONGITUDINAL SECTION. Occasional small pits, 10-12μ in diameter, on the tangential walls of the tracheids. Medullary rays usually uniseriate, very occasionally (about 2 per cent of the rays) biseriate in a portion which is only one cell high. Rays 1-12 cells high (average 4), usually 2-6. Cells more or less square, average tangential diameter 18μ (10-30μ), average height 23·5μ (12-33μ). Medullary rays which are one or two cells high and the outer rows of rays which are more than two cells high have cells which average 25μ in height, and are thus somewhat higher than the cells of the inner rows of the latter type of ray, which average 20μ.

LOCALITY. Yallourn.

COMMENTS. This wood seems to match the fossil wood from Ballarat Tertiary deposits which was described by Kubart (1923) as *Podocarpoxylon smythii*. Kubart considered that the wood which he investigated was the same as that originally described by von Mueller (1883) as *Spondylostrobus smythii*, but that many of the details shown by von Mueller were inaccurate. Kräusel (1949) changed the name given by Kubart to *Podocarpoxylon australe* because he considered that the specific name *smythii* belongs only to fruits which in fact have no connection with the wood.

There are a few differences between the fossil wood from Yallourn and that investigated by Kubart, but they do not seem to be of sufficient importance to warrant the separation of the woods into two species. Kräusel included the wood described as *Mesembrioxylon* sp., Yallourn A. by Nobes (1922) with *P. australe*, but it is doubtful if this is correct. Judging from the text and the illustrations given by Nobes, her material differs from the wood described above and that investigated by Kubart in that it has no wood parenchyma, the pits on the radial walls of the tracheids have relatively very large, circular apertures and are often biseriate and the cross-field pits are circular and about 7-11μ in diameter. These differences appear to be sufficient to separate Nobes's material from *P. australe*.

Podocarpoxylon minor sp. nov.

(Pl. XXI, figs. 1-8)

TRANSVERSE SECTION. Annual rings indistinct. Tracheids rounded, average tangential diameter 21μ (8-33μ), walls 2-5μ thick, primary and secondary walls distinct. Wood parenchyma diffuse, sparse, with occasional globules of resin. Medullary rays uniseriate, without resin.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids moderately abundant, uniseriate, average diameter in the spring wood 10μ (8-13μ). Pits broadly oval, apertures relatively quite large, oval, oblique; the pores on the opposite sides of an individual pit may be at an angle to one another. Transverse walls of the wood parenchyma very thin, more or less smooth, pits of the parenchyma small (longer diameter about 6μ), oval, apertures oblique.

Medullary rays parenchymatous. Horizontal and end walls thin (about 1μ) and more or less smooth, end walls without indentures. Cross-field pits oval, longer diameter 2·5-7·5μ, average 5μ, shorter diameter (which coincides with the long axis of the pore) 2·5-5·5μ, average 4μ. Apertures of the cross-field pits very narrow, oblique, reaching or exceeding the border at either end. Number of pits per cross-field usually 1, rarely 2 or 3; if 2 pits are present, they are more or less vertically placed.

TANGENTIAL LONGITUDINAL SECTION. Occasional pits, 8-13μ in diameter, on the tangential walls of the tracheids. Medullary rays uniseriate, usually 1-3 cells high, average 2, maximum 7. Cells of the medullary rays more or less oval, average tan-

gential diameter 10μ (5-13μ), average height 15μ (8-20μ). Cells of the inner rows of rays which are more than 2 cells high average a slightly lower height than any other ray cells.

LOCALITY. Bacchus Marsh.

COMMENTS. This wood does not seem to match any of the wood previously described from Australian brown coal deposits or that of any other fossil species with which it might reasonably be compared. Hence it is regarded as a new species, but it must be pointed out that it is structurally very similar to *Podocarpoxylon australe*. The main difference between the two species is one of size; in *P. australe* the tangential diameter of the tracheids, the diameter of the pits on the radial walls of the tracheids, the height and tangential diameter of the medullary ray cells and the longer and shorter diameter of the cross-field pits are all appreciably greater than the comparable dimensions of *P. minor*. There is a certain overlap in all these measurements, but the differences between them are all statistically significant. There are other differences between these two woods, but alone these would probably not suffice to separate them; thus in *P. australe* the pores of the tracheid pits are relatively small, resin is abundant in the wood parenchyma and medullary rays and the rays are 1-12 (average 4) cells high, whereas in *P. minor* the pores of the tracheid pits are relatively large, resin is sparse in the wood parenchyma and absent from the medullary rays and the rays are 1-7 (average 2) cells high.

Podocarpoxylon yallournensis sp. nov.

(Pl. XXI, figs. 9-15)

TRANSVERSE SECTION. Annual rings indistinct, occasionally a narrow band of thick-walled cells present. Tracheids very much rounded, average tangential diameter 22μ (10-30μ), walls thin (1-3μ), limits of individual cells and of primary and secondary walls indistinguishable. Wood parenchyma diffuse, moderately abundant, resinous. Medullary rays uniseriate, resinous.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids abundant, usually uniseriate, occasionally partially biseriate, opposite or alternate. Average diameter of the pits of the spring wood 15μ (12-18μ). Pits more or less circular, surface marked by faint radial striations, apertures large and circular. Resinous wood parenchyma very conspicuous, transverse walls very thin, smooth, pits small (diameter about 5μ) and apertures broad.

Medullary rays parenchymatous. Horizontal and end walls thin (about 1μ or less) and more or less smooth, end walls without indentures. Cross-field pits very variable in size and shape, the longer diameter ranging from 3-10μ. Cross-field pit apertures broad or narrow, reaching the border at points which may constitute the ends of either the long or the short axis of the pit. Borders of the pits frequently indistinguishable. Number of pits per cross-field 1-5, usually only 1-3.

TANGENTIAL LONGITUDINAL SECTION. Occasional small pits, about 10μ in diameter, on the tangential walls of the tracheids. Medullary rays uniseriate, usually 1-2 cells high, average 2, maximum 6. Cells of the rays more or less elliptical, average tangential diameter 21μ (10-35μ), average height 28μ (15-40μ).

LOCALITY. Yallourn.

COMMENTS. This wood does not seem to be the same as any of that previously described from Australian brown coal deposits, although it bears some resemblance to the wood from Yallourn named *Cupressinoxylon* sp. by Nobes (1922). However, there are only 1-2 pits in each cross-field in Nobes's material, the apertures of these

pits apparently do not usually reach the border and the medullary rays are usually 1-20, occasionally 1-30 cells high. The work of Bannan (most of which is listed in Bannan 1954) shows that, at least in many North American conifers, the height of the medullary rays is a character which can vary considerably in a single individual, but Greguss (1955) uses the height of the rays in separating the wood of present-day species of *Podocarpus*, *Dacrydium* and *Phyllocladus*, and it seems probable that the very great difference between the height of the rays in Nobes's wood and the one at present under consideration, together with the differences in the cross-field pitting, are sufficient to separate them. Kräusel (1949) considers that *Podocarpoxylon totara* Evans (Evans 1937) includes both *Cupressinoxylon* sp. Nobes and *Mesembrioxylon* sp., Moorlands A., Nobes, but *P. yallournensis* has even less in common with *P. totara* and this species of *Mesembrioxylon* than it has with *Cupressinoxylon* sp., and in fact it is doubtful whether these three species which were united by Kräusel belong together.

Of the other fossil species with which it may be compared, *P. yallournensis* appears to be closest to *Cupressinoxylon antarcticum* Beust from the Tertiary of Kerguelen Island. This wood was fully described by Edwards (1921), who considered that it might in fact belong to *Podocarpoxylon*. From Edwards's description and illustrations, it appears that the cross-field pitting is the same in *P. yallournensis* as in *C. antarcticum*. However, Edwards believed that the appearance of the cross-field pits was probably altered by decay, and in view of this uncertainty and of some differences between the other parts of the two woods, it seems unwise at present to regard them as one species. It is, of course, of interest that this similarity to a Kerguelen form is also shown by *Agathis resinifera*.

Phyllocladoxylon annulatus sp. nov.

(Pl. XXII, figs. 1-11)

Transverse Section. Annual rings conspicuous, 7-23 cells wide. Tracheids rectangular to subrectangular, average tangential diameter 28μ (10-43μ), walls 4-11μ in thickness, thin in the spring wood and very thick in the autumn wood. Primary and secondary walls distinct. Wood parenchyma absent. Medullary rays uniseriate, doubtfully resinous.

Radial Longitudinal Section. Bordered pits on the radial walls of the tracheids abundant, usually uniseriate, occasionally biseriate and opposite or alternate. Bars of Sanio present. Average diameter of the pits in the spring wood 15μ (12-18μ). Pits more or less circular, apertures oblique, rather small, circular to broadly oval with an elongated ridge on each side. The pores on the opposite sides of an individual pit are usually at an angle to one another. Vestured pits (as described by Greguss 1955) occasionally present. Resin rings present, usually very thin.

Medullary rays parenchymatous, cells frequently irregular in outline and similar to those of *Microcachrys* (Patton 1928a). Horizontal and end walls thin (about 1μ) and more or less smooth, end walls without indentures. Cross-field pits oval, large, longer diameter 10-20μ, shorter diameter (which coincides with the long axis of the aperture) 8-13μ. Apertures of the cross-field pits oblique, usually oval and nearly reaching or reaching the border at either end, occasionally slit-like and reaching or exceeding the border. Number of pits per cross-field usually 1, rarely 2 and vertically or horizontally placed.

Tangential Longitudinal Section. Pits on the tangential walls of the tracheids quite abundant, 10-13μ in diameter. Medullary rays uniseriate, usually 1-3 cells high, average 2, maximum 7. Cells of the medullary rays more or less elliptical,

average tangential diameter 9μ (5-15μ), average height 19μ (8-28μ). Cells of the inner rows of rays which are more than 2 cells high average 15μ in height compared with 20μ for the other ray cells. Resin rings usually very thin.

LOCALITY. Yallourn.

COMMENTS. Wood which Kräusel (1949) regards as *Phyllocladoxylon*, but which was originally named *Mesembrioxylon* sp., Yallourn B. by Nobes (1922), has already been described from the Yallourn brown coal, but there is no doubt that it is different from the wood described above. The latter does not agree with any of the other wood from the brown coal which has previously been described, nor with any other fossils, such as the one from Stony Creek (Patton 1928b), with which it might reasonably be compared, and hence it is regarded as a new species.

Cookson and Pike (1954a) described leaves of *Phyllocladus morwellensis* Deane and pollen grains of *P. palaeogenicus* Cookson and Pike from the Yallourn brown coal, and it is possible that these may have come from the same species as *Phyllocladoxylon annulatus*. However, there is no evidence of a connection between the three forms, and, of course, the fossil wood does not necessarily represent a species of *Phyllocladus*. Cookson and Pike suggest that the leaves are unlikely to represent *Phyllocladus aspleniifolius* (Labill.) Hook. f. (syn. *P. rhomboidalis* Rich.), the only existing Australian species of *Phyllocladus*. It is therefore of interest to note that the wood of *Phyllocladoxylon annulatus* is also different from the wood of this species. The wood of *P. annulatus* is rather similar to that of *Phyllocladus trichomanoides* D. Don., one of the two species of *Phyllocladus* which occur in New Zealand at the present day. The cross-field pits of the two woods are alike, and the ridges on the edge of the aperture in the tracheid pits of the fossil match those of the recent species. However, neither of these characters is restricted to *Phyllocladus*, and it cannot be said that all structures in the fossil are exactly the same as those of *P. trichomanoides*.

ANGIOSPERMAE

CASUARINACEAE

Casuarina latrobei sp. nov.

(Pl. XXIV, figs. 1-10)

TRANSVERSE SECTION. Annual rings indistinct or absent. Vessels large, circular to elliptical, sparse, scattered, often filled with tyloses. Vasicentric tracheids present. Fibres thick-walled, lumen almost obliterated. The fibres are arranged in more or less rectangular areas bounded radially by the medullary rays and tangentially by bands of parenchyma 1-3 cells wide. Medullary rays of two kinds, uniseriate and multiseriate, the latter heterogeneous and consisting of parenchyma with an interlacing network of conspicuously pitted fibres.

RADIAL LONGITUDINAL SECTION. Tangential bands of parenchyma conspicuous, fibres without obvious pitting. Vasicentric tracheids strongly pitted. Heterogeneous medullary rays very high, parenchyma cells irregular in size, network of pitted fibres conspicuous.

TANGENTIAL LONGITUDINAL SECTION. Uniseriate medullary rays abundant. Network of pitted fibres in the multiseriate rays very conspicuous.

LOCALITY. Yallourn.

COMMENTS. As far as is known, there are no previous accounts of the detailed structure of *Casuarina* wood from any Australian Tertiary deposits. However, the occurrence of *Casuarina* wood at Yallourn was noted by Chapman (1925), a *Casu-*

arina cone from the Yallourn brown coal was recorded by Pike (1952) and Cookson and Pike (1954b) described pollen grains of *Casuarinidites cainozoicus* from the same locality. It is probable that some of these forms belong to the same species, but there is no evidence regarding this point at present. The specific name for the wood described in the present paper refers to the extensive brown coal deposits (including the ones worked at Yallourn) of the Latrobe valley.

Proteaceae

Banksia fossilis sp. nov.

(Pl. XXIII, figs. 8-15)

Transverse Section. Vessels rather thin-walled, variable in size and shape, arranged in groups which are associated with wood parenchyma to form curved tangential festoons between the large medullary rays. Wood parenchyma in bands, apparently 1-3 cells wide, on the concave side of these festoons. Occasional tracheids apparently also present in the festoons. Medullary rays of two distinct types, small uniseriate rays and large multiseriate ones which are usually about 5-9 cells wide but may be up to at least 14 cells wide. Vessels, parenchyma and medullary rays often filled with a reddish-brown substance, presumably resin. Fibres very thick-walled, lumen almost obliterated, pits simple. Fibres arranged in curved tangential bands between the festoons of vessels and wood parenchyma.

Radial Longitudinal Section. Pits of vessel segments small. Cells of uniseriate medullary rays apparently all erect.

Tangential Longitudinal Section. Uniseriate medullary rays usually 1-5 cells high, maximum 12. Multiseriate rays up to at least 2·5 mm. high and at least 0·3 mm. wide.

Locality. Bacchus Marsh.

Comments. This fossil clearly has the type of wood structure which Chattaway (1948a) shows to be characteristic of many recent members of the family Proteaceae. The wood structure of the fossil cannot be used to identify it as a particular genus as, from the information given by Chattaway, it could belong to *Banksia*, *Dryandra* or *Hakea*. However, the nature of the bark on the fossil definitely places it in *Banksia*, and this identification is supported by the fact that the wood structure seems to have slightly more in common with that of *Banksia* than *Hakea*, while the present-day distribution of *Dryandra* (which occurs only in Western Australia) renders it somewhat unlikely that the fossil belongs to this genus. Chattaway (1948b) gives details of the vascular tissue which may occur in the medullary rays of *Banksia* and *Dryandra*; this feature is not known in any other members of the Proteaceae, and hence could be used to identify a fossil as either *Banksia* or *Dryandra*. Unfortunately, no vascular tissue was observed in the rays of the fossil described above. This may have been due to the frequent distortion of the rays and the generally unsatisfactory nature of the sections, but Chattaway points out that the frequency of vascular tissue in the rays is variable, and its absence, even in perfect sections, would not disprove the identification of the fossil as *Banksia*.

Chattaway (1948a) shows that, in many genera with the *Banksia* type of structure, there is a great variation in vessel size, the smaller ones being little bigger than the parenchyma cells with which they are associated. The walls of the vessels of the fossil are rather thin, and, in the absence of satisfactory longitudinal sections, small vessels cannot be distinguished from parenchyma cells. Consequently, although it appears probable that the bands of parenchyma on the concave side of the festoons

are 1-3 cells wide, it is not possible to be certain on this point, or to determine whether the vessels grade into tracheids.

There are no known records of the detailed structure of proteaceous woods from Australian Tertiary deposits with which the wood described above can be compared, and therefore it must be regarded as a new species. However, there is an abundance of other evidence to show that *Banksia*, or at least forms closely related to it, existed at the time when the brown coal was formed. Thus Deane (1925) recorded *Banksia* leaves from Yallourn, Cookson and Duigan (1950) described *Banksia* cones and the leaves of six species of *Banksieaephyllum* from the Yallourn open cut and Cookson (1950) described pollen grains, which she named *Banksieaeidites*, from the same locality.

Discussion

From the material examined, it appears that the forests which formed the brown coal were almost purely coniferous, and hardwoods, although occasionally present, may be regarded as accidental. The deposits consist largely of tree-trunks which fell where they grew; some fell while still on the stump, and the roots are therefore upright, while others rotted at water level, leaving the stumps still in their original position.

Owing to the general absence of mineral matter in the coal, the conclusion must be drawn that the trees grew in a swamp which was sinking slowly, so slowly that, during the lifetime of the trees, water did not encroach seriously upon the trunks and the trees could therefore reach an age and size equivalent to those on dry land. In the case of trees which fell from the stump, it may be concluded that there were periods of equilibrium in the sinking and that the trees decayed at the water-air level.

The swamp in which the forests occurred must have provided a very soft, organic medium for the growth of the vegetation, and it is surprising that this permitted large trees to obtain an adequate root-hold. This does not appear to have been due to the roots having reached a very great depth, and there is no evidence of any provision for a supply of air to the roots as in the Mangrove (*Avicennia officinalis*) or the Bald Cypress (*Taxodium distichum*).

One of the most interesting woods present in the brown coal is that of the Kauri Pine, *Agathis*, for this genus extends today only from Malaya in the north to the northern part of New Zealand. In Australia, Kauri does not come further south than Queensland, but in New Zealand it extends southwards to a latitude similar to that of Melbourne. However, the temperatures in the New Zealand areas are higher than those of Melbourne, although not as high as those of Sydney.

According to Cranwell and Moore (1936), who describe the vegetation with which Kauri occurs, the plant association is definitely rain-forest. They also state that Kauri formerly grew in the South Island. The present occurrence in the extreme north of New Zealand may therefore be regarded as the last remnant of its retreat northwards.

The temperatures at Gabo Island (which is just off the extreme east of Victoria) are very similar to those of Auckland, N.Z., where Kauri grows at the present day, but, although rain-forests extend down the east coast of Australia and just pass Gabo Island, Kauri is left far to the north. However, the rain-forest is probably not a relic, as is the Kauri in New Zealand, but a readvance southward due to a climatic amelioration since Pleistocene times.

Although far from the tropics, Kauri is maintained in New Zealand because of the mild winter temperatures and the even distribution of the rainfall throughout the year. All other areas in which *Agathis* grows are tropical, and its presence in

Victoria during Oligocene times indicates a climate which was warmer than that of the present day.

It seems probable that at least some of the woods recorded here as *Podocarpoxylon* do in fact represent species of *Podocarpus*, and in any case there is other independent evidence of the presence of *Podocarpus* in the brown coal at both Yallourn and Bacchus Marsh (Cookson and Pike 1953). However, this does not imply any particular climatic conditions, as *Podocarpus* has a wide distribution at the present time, ranging from Australia northwards to Japan, westwards to South Africa and eastwards to South America and the West Indies. Within Australia, it occurs over a wide range of climatic conditions from the Australian Alps, where the snow lies deep for several months of the year (*P. alpina* R.Br.), to the tropical lowlands (*P. elata* R.Br.). Florin (1940) considers that *Podocarpus* originated in the Southern Hemisphere and that its distribution in Tertiary times was as far south as Antarctica. If this is true, the presence of the genus in the brown coal is not surprising, particularly in view of the fact that *Podocarpus* has persisted to the present day and still has a very wide distribution.

In spite of the fact that the situation may be confused in some cases by the presence of compression wood (see p. 129) it is of interest to note that, in the coniferous woods identified here from the brown coal, there are four species in which the annual rings are ill-defined or absent and one in which they are sharply defined. The lack of obvious rings of growth is, at the present day, a feature of the wood of tropical species—e.g. *Agathis* and *Araucaria* in the high rainfall areas (Patton 1928a)—but it is not restricted to such species. Thus, in Victoria today, none of the trees such as the Murray Pine (*Callitris*) or *Eucalyptus* shows sharply defined rings of growth comparable with those of trees from the northern temperate lands. This is true for Victorian trees from areas with a high or a low rainfall, and is due to the fact that the winter temperatures are not sufficiently low to cause a cessation of activity. Thus the absence or lack of definition of annual rings in the wood of the four fossil species does not necessarily indicate climatic conditions which differ from those of the present day.

The presence of fossil wood with sharply defined annual rings complicates the matter. The very distinct rings of *Phyllocladoxylon* are similar to those found in the wood of *Athrotaxis*, *Phyllocladus* and *Dacrydium* in Tasmania at the present day (Patton 1928a), and are as well defined as those of the Northern Hemisphere conifers. In the colder parts of the Northern Hemisphere, the well-defined rings of growth in both angiospermous and gymnospermous trees are accompanied by annual defoliation in the former, and are associated with winter temperatures which are too low for growth. However, even in Tasmania the angiospermous trees lack well-developed annual rings and, with the exception of the shrub *Nothofagus gunnii* (Hook.) Oerst., none of the woody angiosperms is deciduous.

Phyllocladoxylon persisted in Australia from the Oligocene to the Pleistocene, but is now extinct, and the reason for the extinction of trees with well-defined annual rings on the mainland while they still exist in Tasmania is not clear. Tasmania is colder than Victoria, and therefore the low temperatures of the glacial periods cannot have been the cause. Nor can it have been dryness for, although there have been changes in the vegetation during the Tertiary and Quaternary periods, there is a core of vegetation with tropical affinities which has persisted to the present day (Patton 1933). It can only be assumed that this character of well-defined rings is a feature of the species and is independent of environment. Hence the wood of *Phyllocladoxylon* at Yallourn is not inconsistent with the presence of other species in which growth rings are ill-defined or absent.

The only angiosperm woods found in the brown coal were those of *Casuarina* and *Banksia*. Wood belonging to these genera has only been found in the uppermost layers of the brown coal, where it was usually only spasmodically present; it is probable that this occurrence is quite accidental and that the logs were derived from the high ground surrounding the swamp. However, there was an almost pure layer of *Banksia* wood at one locality at Bacchus Marsh; this was several feet in thickness, and it suggests that, although a depression existed, conditions suitable for coniferous species no longer prevailed.

Casuarina and *Banksia* are typically Australian genera, both of which are now widespread from eastern to western Australia. The former, however, extends into northern Australia, and has one species which passes across to the coasts of tropical islands and forms part of the coastal forest (Schimper 1903). The genus *Banksia* is found in areas with a low to moderate rainfall; in Victoria today there are five species, one on the coastal dunes, one on the heath, one in the Mallee, one in east Gippsland forests and one in the forests near Melbourne. *Casuarina* is not as large a genus as *Banksia*, but its species extend over a wider range of environmental conditions. Thus *Casuarina decaisneana* (F.v.M.) occurs in central Australia where the rainfall is less than five inches per year, while *C. cunninghamiana* Miq. grows on river-banks in coastal New South Wales where the annual rainfall is over ninety inches. However, the genera *Banksia* and *Casuarina* may both be regarded, in general, as xerophytic. Xerophytism is not, of course, controlled only by rainfall, but is also dependent on the quality of the soil. The presence of *Banksia* and *Casuarina* around the swamp areas forming the brown coal suggests that the soil on the hills was thin, and that hence the vegetation there did not reflect the highly favourable climatic conditions.

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Explanation of Plates

Photographs by Dr. Suzanne L. Duigan

PLATE XX

Podocarpoxylon australe (F.v.M.) Kräusel

Fig. 1.—Transverse section. × 100.

Fig. 2.—Transverse section showing distorted tracheids, distorted medullary rays and abnormally large parenchyma cells. × 100.

Fig. 3.—Transverse section. × 100.

Fig. 4.—Transverse section of distorted tracheids and some of the abnormally large parenchyma cells shown in Fig. 2. × 330.

Fig. 5.—Transverse section showing distorted tracheids and distorted medullary rays. × 100.

Fig. 6.—Radial longitudinal section showing the high outer cells and the low inner cells of a medullary ray which is four cells high. × 600.
Fig. 7.—Radial longitudinal section showing the pits of a single cross-field. × 1,000.
Fig. 8.—Radial longitudinal section of a medullary ray showing the arrangement of the cross-field pits and the slit-like extensions to their pores. × 600.
Fig. 9.—Tangential longitudinal section. × 100.
Fig. 10.—Radial longitudinal section, showing pits on the radial wall of a tracheid. × 600.
Fig. 11.—Radial longitudinal section, showing slit-like extensions to the apertures of the pits on the radial walls of the tracheids. × 600.
Fig. 12.—Tangential longitudinal section, showing a medullary ray and spiral checks on the walls of the tracheids. × 330.

Plate XXI

Podocarpoxylon minor sp. nov.

Fig. 1.—Transverse section. × 100.
Fig. 2.—Transverse section. × 330.
Fig. 3.—Tangential longitudinal section. × 100.
Figs. 4, 5.—Radial longitudinal section, showing the pits on the radial walls of the tracheids. × 600.
Fig. 6.—Radial longitudinal section of a medullary ray, showing the arrangement of the cross-field pits. × 600.
Fig. 7.—Radial longitudinal section of a medullary ray, showing a cross-field pit. × 1,000.
Fig. 8.—Tangential longitudinal section of a medullary ray. × 330.

Podocarpoxylon yallournensis sp. nov.

Fig. 9.—Transverse section. × 100.
Fig. 10.—Radial longitudinal section. × 100.
Fig. 11.—Tangential longitudinal section. × 100.
Fig. 12.—Transverse section. × 330.
Fig. 13.—Radial longitudinal section, showing the pits on the radial walls of the tracheids. × 600.
Fig. 14.—Radial longitudinal section of a medullary ray, showing the pits in two cross-fields. × 1,000.
Fig. 15.—Tangential longitudinal section of two medullary rays. × 330.

Plate XXII

Phyllocladoxylon annulatus sp. nov.

Fig. 1.—Transverse section, showing the junction of spring and autumn wood. × 100.
Fig. 2.—The same. × 330.
Fig. 3.—Radial longitudinal section. × 100.
Fig. 4.—Radial longitudinal section, showing the pits and Bars of Sanio on the radial walls of the tracheids. × 600.
Fig. 5.—Radial longitudinal section of a medullary ray, showing the arrangement of the cross-field pits. × 600.
Fig. 6.—Radial longitudinal section, showing a single cross-field. × 1,000.
Fig. 7.—Radial longitudinal section, showing vestured pits on the radial wall of a tracheid. × 1,000.
Figs. 8, 9.—Tangential longitudinal section of tracheids, showing resin rings. × 600.
Fig. 10.—Tangential longitudinal section. × 100.
Fig. 11.—Tangential longitudinal section of a medullary ray. × 330.

Agathis resinifera sp. nov.

Fig. 12.—Radial longitudinal section. × 100.
Fig. 13.—Transverse section, showing the arrangement of the resin plates. A few abnormal cells, in which the secondary wall has disintegrated, are present. × 100.
Fig. 14.—Transverse section, showing the junction of spring and autumn wood. × 100.
Fig. 15.—Tangential longitudinal section. × 100.
Fig. 16.—Tangential longitudinal section, showing a medullary ray and a resin plate. × 330.
Fig. 17.—Transverse section, showing a distorted tracheid and stages in the disintegration of the secondary wall of other abnormal tracheids. × 330.

Plate XXIII

Agathis resinifera sp. nov.

Fig. 1.—Transverse section of normal wood, showing resin plates in some of the tracheids next to the medullary ray. × 330.

Figs. 2, 3, 4.—Radial longitudinal section, showing the pits on the radial wall of a tracheid at high, medium and low focus respectively. × 1,000.

Fig. 5.—Radial longitudinal section, showing the pits on the radial wall of a tracheid. × 600.

Fig. 6.—Radial longitudinal section of a medullary ray, showing the arrangement of the cross-field pits. × 330.

Fig. 7.—Radial longitudinal section, showing the pits in a single cross-field. × 1,000.

Banksia fossilis sp. nov.

Fig. 8.—Transverse section, showing multiseriate medullary rays with dark festoons of vessels and wood parenchyma between them, and the lighter coloured patches of thick-walled fibres. × 50.

Fig. 9.—Part of the same transverse section. × 100.

Fig. 10.—Tangential longitudinal section of part of a small uniseriate medullary ray. × 330.

Fig. 11.—Radial longitudinal section of part of a large multiseriate medullary ray. × 100.

Fig. 12.—Transverse section of vessels and fibres on the convex side of a festoon. × 330.

Fig. 13.—Radial longitudinal section of a vessel, showing the pitting. × 330.

Fig. 14.—Radial longitudinal section, showing fungal hyphae and the junction of two medullary ray cells. × 330.

Fig. 15.—Tangential longitudinal section, showing fibres, small uniseriate medullary rays and part of two large multiseriate rays; the cells of the multiseriate rays are all distorted. × 100.

Plate XXIV

Casuarina latrobei sp. nov.

Fig. 1.—Transverse section, showing uniseriate and multiseriate medullary rays, scattered vessels with tyloses, and areas of fibres subdivided by tangential bands of wood parenchyma. × 100.

Fig. 2.—Transverse section of a large multiseriate medullary ray, showing parenchyma and fibres. × 100.

Fig. 3.—Transverse section, showing uniseriate medullary rays and thick-walled fibres. × 330.

Fig. 4.—Radial longitudinal section of a large multiseriate medullary ray. × 100.

Fig. 5.—Radial longitudinal section of a uniseriate medullary ray. × 330.

Fig. 6.—Radial longitudinal section, showing the pitting of the vasicentric tracheids. × 330.

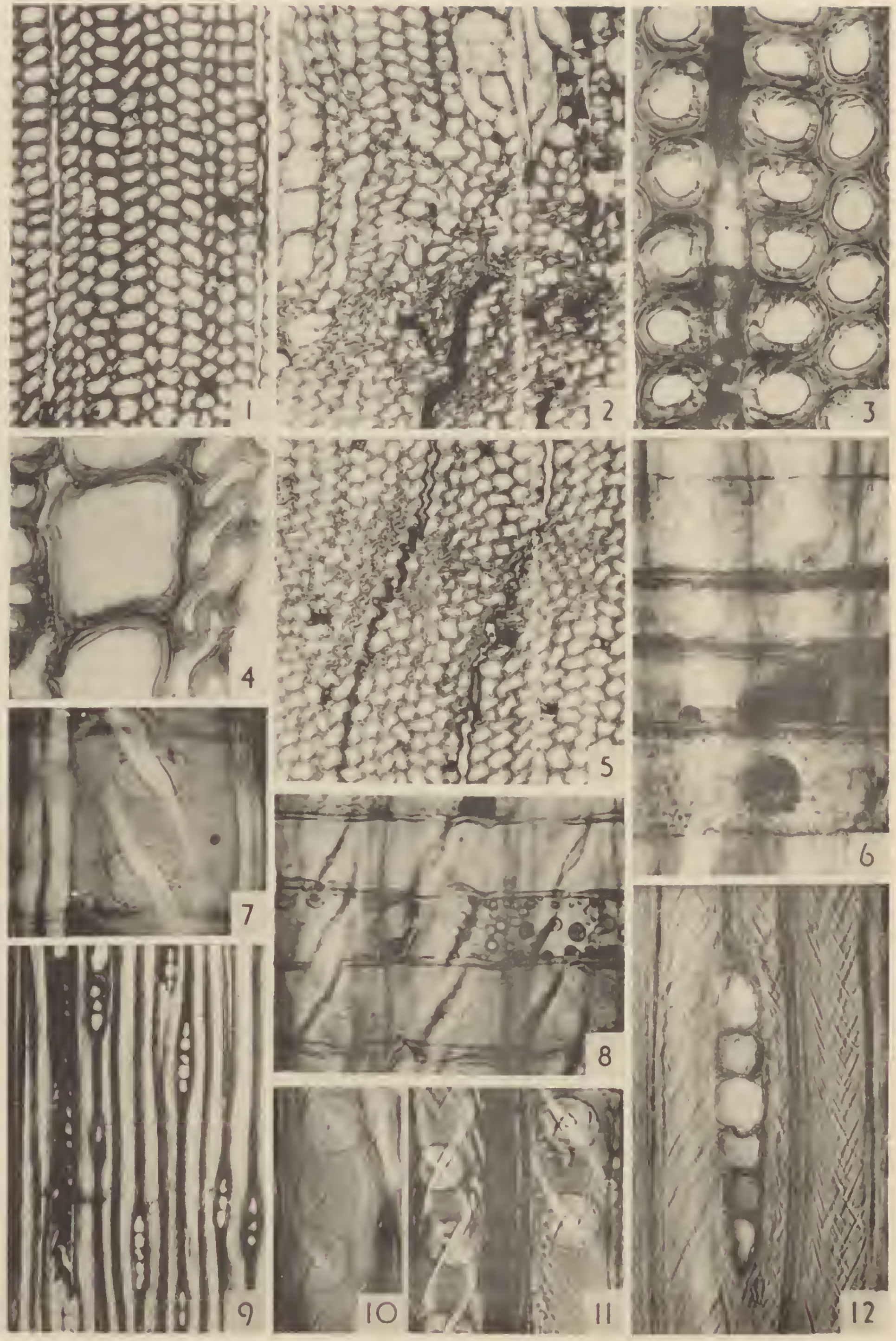
Fig. 7.—Tangential longitudinal section, showing fibres, uniseriate medullary rays and a vessel. × 100.

Fig. 8.—Tangential longitudinal section of a large multiseriate medullary ray, showing the network of fibres. × 100.

Fig. 9.—Tangential longitudinal section of a large multiseriate medullary ray, showing the fibres cut longitudinally. × 330.

Fig. 10.—The same, showing fibres cut transversely. × 330.

Fig. 11.—The same. × 200.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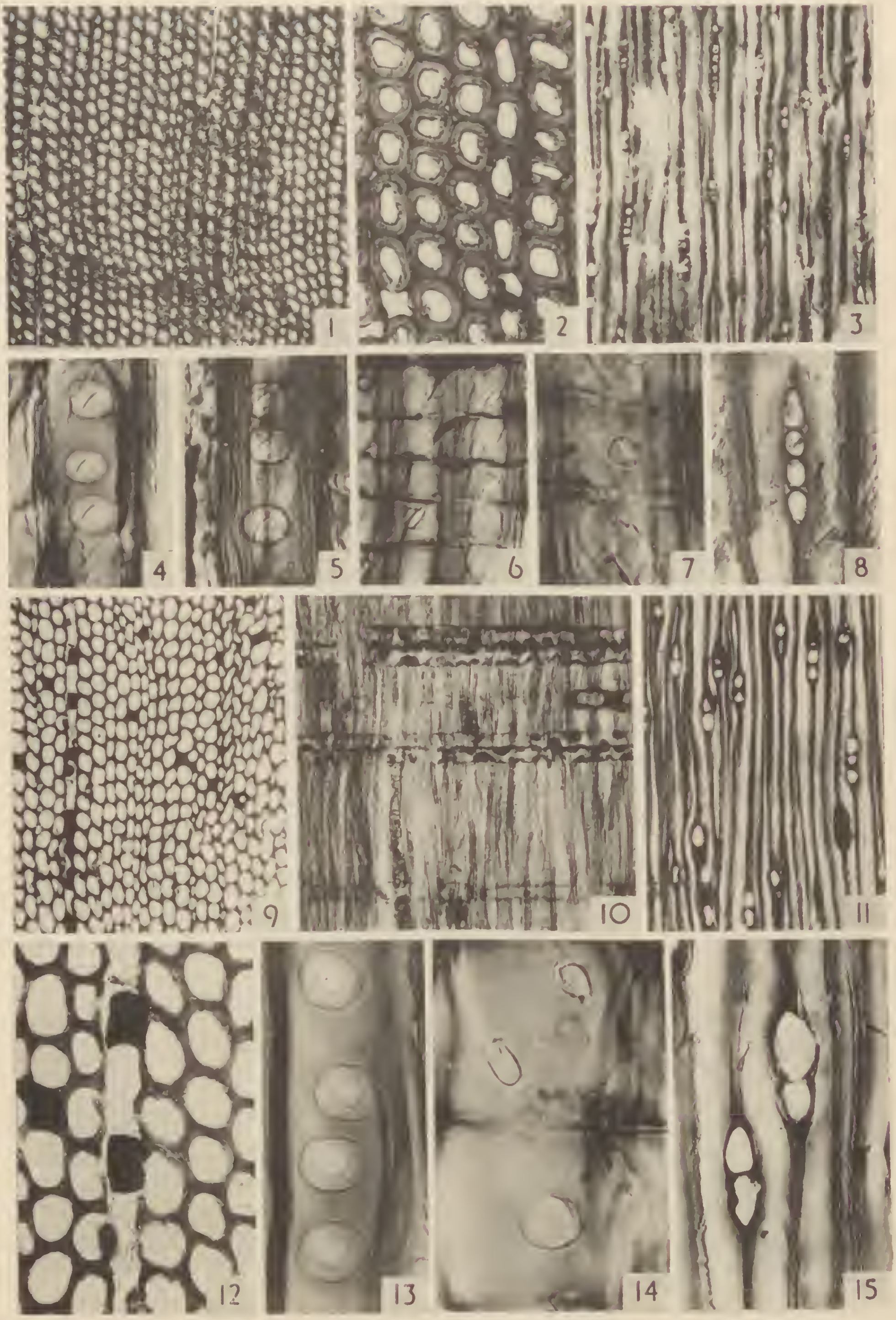
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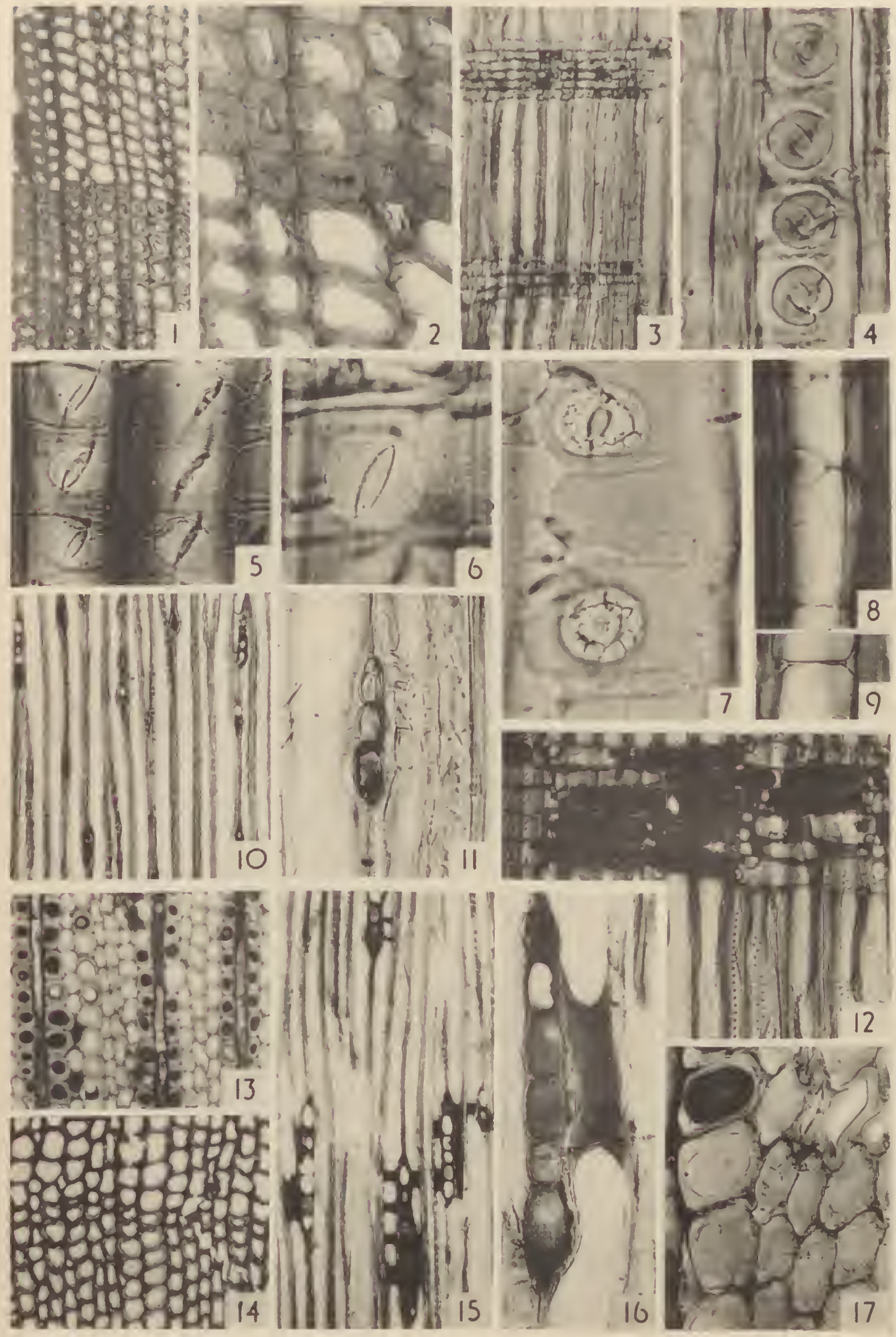
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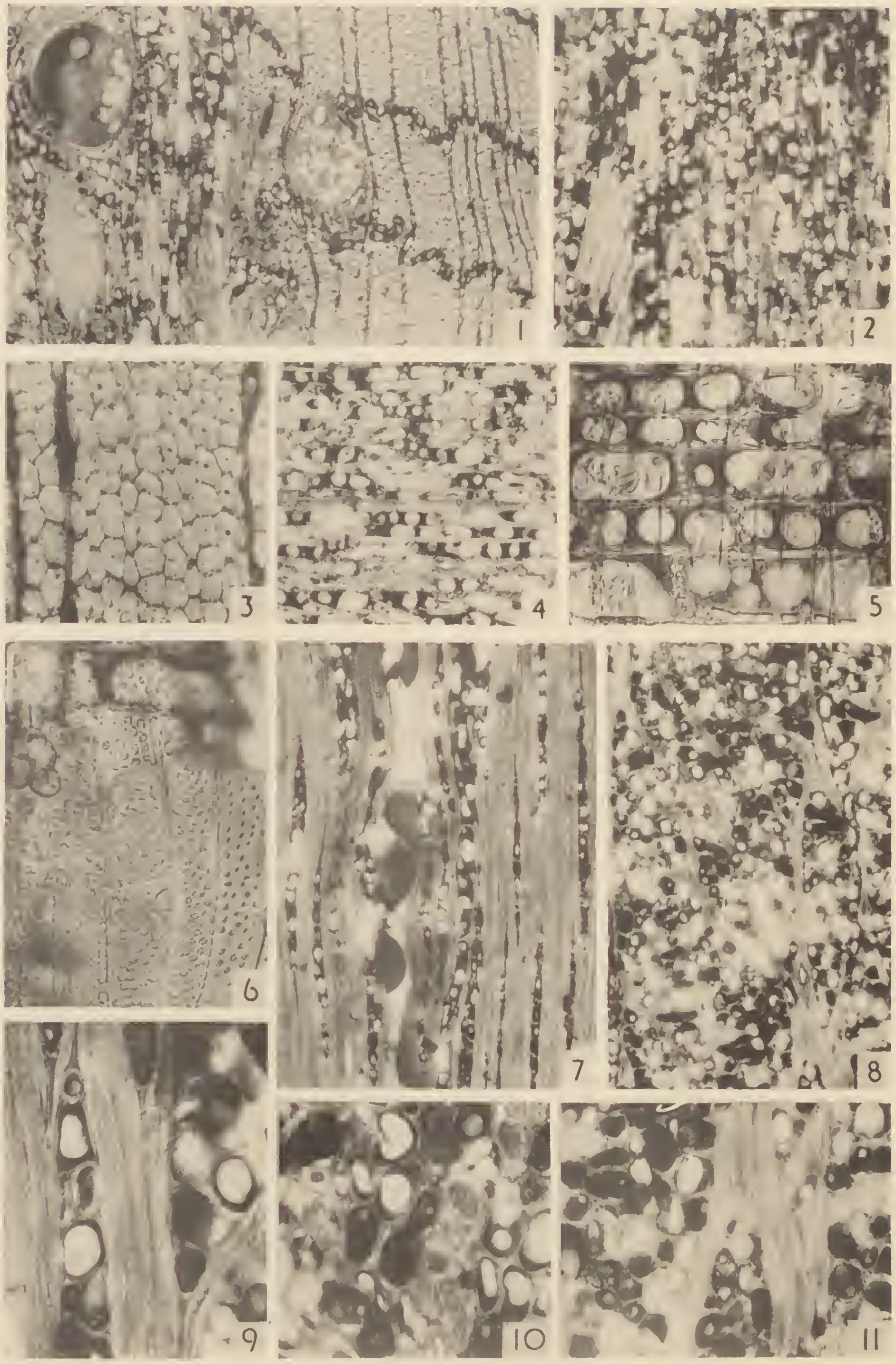
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THE GENUS *DIEMENIANA* DISTANT WITH DESCRIPTION OF A NEW SPECIES

(HEMIPTERA-HOMOPTERA, CICADIDAE, TIBICININAE)

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[Read 12 December 1957]

Abstract

The genus *Diemeniana* Distant is confined to the southern parts of Australia and the island of Tasmania, two of the Tasmanian species, *D. turneri* and *D. tillyardi*, are mountain insects. Unlike most cicadas *Diemeniana* do not favour high trees or heavily forested country, preferring open country carrying low heathy bushes and grass tussocks.

It is unusual to capture specimens at heights greater than 3 ft. from the ground. In no species is the song loud, it may be compared with a type of "rasping" which is audible at a considerable distance. At very close quarters it is often difficult to locate a specimen although it may continue singing while being closely observed.

The key to the species is built up from a careful and detailed study of common characters. All are figured. These are supplemented with detailed drawings of special structural features. One new species is described, and a transfer to this genus is made of a species of *Abricta* (Cicada), *A. aurata* (Walker).

Walker's name *aurata* was preoccupied by *Cicada aurata* Linne, 1758, so Kirkaldy's name *euronotiana* (1909) must be used. The name *tasmani* Kirkaldy (1909) must also be used for *coleoptrata* (Walker) preoccupied by *Cicada aurata* Linne, 1758.

Introduction

Specimens of the genus *Diemeniana* Distant have generously been lent for study by the Australian Museum in Sydney, the South Australian Museum and the Tasmanian Museum, and the writer has also studied the specimens in the National Museum of Victoria and in his own collection.

The generic characters set out by Distant (1906) while partly satisfactory are not sufficient to define the genus accurately. The descriptions of species in this paper are designed to set out relationships along similar lines.

Up to the present time nothing is known of the earlier stages of any species of *Diemeniana*. Therefore the duration of any one complete life cycle is unknown.

Field observations reveal that at least three of the species, *D. euronotiana*, *D. tasmani* and *D. neboissi*, are partial to resting on long grass, and to a lesser extent, low bushes, at an average height of between 1 and 2 ft. from the ground. *D. tasmani* and *D. neboissi* may be sought on grassy river or creek flats; *D. euronotiana*, by far the most widely distributed species (Tasmania to Barrington Tops, N.S.W.), occurs in open grassy bushland country, near, and to approximately 1000 ft. in Tasmania and Victoria. Going further north into New South Wales it becomes more and more a mountain insect. This can be followed from the specimen label data given later in this paper. *D. turneri*, as far as at present known, is restricted to Tasmania, and is a mountain species being recorded from the summit of Mt. Wellington (4000 ft.) in open places carrying stunted vegetation. The same may be said of the apparently rarer *D. tillyardi*, also confined as far as at present known to the Cradle Mountain region of Tasmania. The six species now included in *Diemeniana* are confined to south-eastern Australia. December, January and February are the months during which to seek them.

D. coleoptrata = *D. tasmani* Kirkaldy was selected by Distant (1906) as the type species; *D. richesi* was added in 1913; *D. turneri* in 1914; *D. tillyardi* in 1917; *D. neboissi* in 1957; and *Cicada aurata* = *Abricta aurata* (Walker) = *Abricta euronotiana* Kirkaldy, described in 1850, is now included in Diemeniana.

TABLE 1

Distribution of Diemeniana

Species	Qld.	N.S.W.	Vic.	Tas.	S.A.	W.A.
euronotiana	—	+	+	+	—	—
tasmani	—	+	+	+	—	—
neboissi	—	+	+	—	—	—
turneri	—	—	—	+	—	—
tillyardi	—	—	—	+	—	—
richesi	—	+	—	—	—	—

Summary of External Morphology

Dark coloured species with rather stout bodies approximately two and a half times as long as broad; anterior wings rounded, either vitreous or infuscate, with a well defined sub-apical darker marking.

HEAD. Punctate or sculptured, approximately two and a half times as wide as long, tri-lobed when viewed dorsally, median (frons) lobe largest; ocelli distinct, frons strongly convex, more or less grooved medianally and longitudinally in front; transverse ridges eight in number, interstitial furrows well defined. Rostrum extending to distal of middle coxae.

THORAX. Approximately one and a third times as long as broad, punctate, granulose, or sculptured; on each side of median two or three sulci, posterior margin strongly developed. Mesonotum bearing a raised cruciform process dorsally and posteriorly, metanotum carinate or ridged, transversely straight or almost so.

LEGS. Femora of anterior pair much thickened and very strongly developed, anterior edge tridentate, the proximal tooth being longest. Posterior tibiae with two or three sharp spines along the outer edge, and from three to five along the inner.

WINGS. Length of anterior equal to or slightly longer than body, approximately two and a half times their width; length of posterior wings about, or less than one and a half times their width.

ABDOMEN. Almost smooth or finely and sparsely punctate, dusted dorsally in places with very short fine golden hairs, ventrally more generally with fine longer dark hairs interspersed in places with short golden ones. Tympani (males) visible dorso-laterally on first abdominal segment, translucent with darker markings. Operculae (males) fairly wide to wide apart, margins more or less recurved, interior angles usually more acute than exterior.

Measurements of each species are listed in Table 2. All available specimens of both sexes were measured, body length being taken from anterior apex of frons to tip of abdomen; wing lengths from bases to apices, widths at maximum.

General

Full label data of all specimens examined are included. These are given because in the cases of *D. tillyardi, D. turneri,* and *D. neboissi,* comparatively few specimens are as yet represented in collections. The types of all but two species are in the British Museum (Natural History); that of *D. tillyardi* is in the Australian Museum. The writer was therefore unable to study all the types. The Australian Museum

generously lent a paratype of *D. tillyardi*; therefore identifications of the other species were made and checked from original descriptions.

The two species in the most archaic Family of Cicadas, the *Tettigarctidae*, show in the anterior wings a strong transverse line suggesting the beginnings of division into corium and membrane. In the Sub-order *Heteroptera* of the *Hemiptera*, the anterior wing is a hemielytron, having the basal half developed into a harder coriaceous, normally opaque or semi-opaque portion, and an outer thinner membraneous portion called the membrane. The clavus (anal area) also is usually coriaceous and separated from the corium by the claval suture (Cu2). This transverse line is apparent (as in *Tettigarcta*) to a much lesser extent in *D. tasmani* and *D. neboissi*, and is more pronounced in some specimens than others. This may be an indication that *Diemeniana* is, as *Tettigarcta* is thought to be, of Antarctic origin.

Some species belonging to the genus *Melampsalta* superficially resemble *Diemeniana*; the former however have the anterior wings at least one and a third times the length of the body which is three times its width, and the interior margins of the operculae are normally very wide apart. Species of *Melampsalta* are much less easily approached than *Diemeniana*, and many species of the former are partial to resting on dead bushes and trees that have been killed by fire. In such cases they are difficult to locate, their dark colour affording an excellent camouflage when resting on the charred wood.

Key to the Species of the Genus Diemeniana

1. Wings clear vitreous, sub-apical marking of anterior wings bordering cross veins from M1 to R3; operculum black, brownish-black, or marked with dark brown or black; anterior femora tridentate, coxal cavities pinkish-red; frons black, densely hairy .. *turneri* Dist.

   Operculum not entirely black or brownish-black, widely margined pale yellowish-brown; frons dark brownish-black, densely hairy, its lateral margins widely pinkish-brown .. 2

2. Costal vein of anterior wings pinkish-red, sub-apical marking more widely bordering cross veins than in *turneri*; pronotum with a clear median yellowish-brown dorsal marking; mesonotum with a similar triangular marking on either side of the mid-dorsal .. .. *tillyardi* Hardy

   Sub-apical marking of anterior wings broadly bordering cross veins from M1 to R3, sharply defined, smoky black; frons shining black, its lateral margins broadly pale yellowish-brown 3

3. Operculae pale yellowish-brown, exterior third of base black; coxal cavities of anterior legs pale yellowish-brown; anterior femora with a fourth minute tooth at base of third (distal) near tibia .. .. *euronotiana* Kirkaldy

   Anterior wings not clear vitreous; sub-apical marking widely bordering cross veins from M1 to R3, operculae not black or brownish-black 4

4. Anterior wings infuscate, all veins brown, a fuscous patch in cell between M4 and Cu1, operculae golden yellow with narrow black basal margin which extends just beyond lateral angles .. .. *richesi* Dist.

   Anterior wings darkly infuscate; sub-apical marking widely bordering cross veins from M1 to R2 5

5. Costal vein dark reddish-brown; posterior wings faintly infuscate in cubito-anal area; coxal cavities of anterior legs light smoky yellowish-brown; operculae pale yellowish-brown .. .. *tasmani* Kirkaldy

   Anterior wings pale infuscate suffused yellowish towards base; frons black, gradually lightening to pale yellowish-brown laterally and towards clypeus; coxal cavities of anterior legs pale yellowish 6

6. Sub-apical marking of anterior wings broadly black, bordering cross veins from M1 to R2; posterior wings vitreous suffused yellowish-brown near base in cubito-anal area; operculae pale yellowish .. .. *neboissi* sp. nov.

TABLE 2

Measurements (mm.) of species of Diemeniana

Species	No. Examined	Body Length			Length of Anterior Wing			Width of Anterior Wing			Length of Posterior Wing			Width of Posterior Wing		
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
D. tillyardi	4♂♂	20	23	21·5	21	23	22·5	9	10	9·2	13	15	14	8	9	8·7
D. turneri	21♂♂	20	23	21·4	20	23	21·9	8	9	8·8	13	16	14	8	9	8·9
	5♀♀	21	24	22·6	22	24	23	9	10	9·6	14	16	15·2	9	10	9·6
D. tasmani	77♂♂	15	22	18·6	17	24	21·4	7	10	9	10	13	11·1	6	9	8·5
	9♀♀	16	20	18·2	19	22	20·3	7	9	8·5	11	13	11·7	7	9	7·8
D. euronotiana	37♂♂	14	18	17·1	13	17	15·4	5	8	6·1	8	11	10	5	6	5·9
	4♀♀	15	16	15·5	14	15	14·8	5	6	5·8	9	10	9·8	5	6	5·3
D. neboissi	26♂♂	17	21	18·8	18	22	19·6	7	9	8·1	11	15	12·4	7	9	7·7
	1♀			19			19			8			13			8
D. richesi	1♂			18			17			7			11			5

Diemeniana turneri Distant

Diemeniana turneri Distant 1914. *Ann. Mag. Nat. Hist.* (8) 14: 325.

As far as is at present known this species is confined to Tasmania, and appears on the wing during the months of January and February. Most of the specimens examined by the writer were captured on Mt. Wellington at about 4000 ft. A note by Mr. Turner (Distant 1914) states that he captured a specimen among stunted vegetation on a very exposed and windy spot. The sexes are similar, so a description of the male is given.

AVERAGE LENGTH. Male 21·4 mm.; female 22·6 mm.

HEAD. Almost as wide as pronotum, intense dull black, finely punctate, clothed with fairly long black hairs, a small reddish-orange depressed spot at vertex where it is widest, gradually narrowing forwards in a groove which extends between the posterior ocelli; another reddish-orange spot on summit of frons which is almost flat, punctate; median groove narrowing from apex to posterior margin. Ocelli garnet vitreous, anterior in line with fore margin of eyes; distance between two posterior slightly greater than that between the anterior and each posterior. Antennae black. Frons black, thickly clothed with long black hairs, a pinkish brown band along each side from summit to half way, transverse ridges 9 in number, shining black, interstitial grooves duller black. Clypeus black, acutely ridged vertically, grooved along apex of ridge, approximately half as long as frons. Labrum black, pinkish-brown along anterior margin. Labium black, pinkish-brown along anterior margin to approximately one third. Genae black, thickly clothed with long black hairs, edges finely brown. Eyes brownish-black, orbits fringed with greyish-white hairs beneath and round to anterior margin of pronotum.

THORAX. Width 7 mm., black, finely punctate, clothed above, and more densely beneath, with black hairs. Pronotum with three sulci on each side, a median narrow reddish-orange longitudional marking reaching the apex of a transverse ridge which extends half way down each side parallel with the narrow reddish-orange posterior margin from which it is separated by a groove. Extreme edges very strongly carinate, produced in the middle to form a blunt tooth. Mesonotum black, slightly more finely punctate than pronotum; a pinkish-brown spot on either side of the median at about one third, another similar but more elongate spot laterally near the base of the anterior wings. Cruciform elevation uniformly black, slightly shining, lightly punctate, bearing a few short golden hairs. Metanotum black, finely tipped reddish-orange, straight, transverse, a central tubercle between it and posterior angles of the cruciform elevation. Beneath, the coxal cavities are broadly encircled reddish-brown.

WINGS. Anterior, male, average length 21·9 mm., width 8·8 mm.; female, 23·0 mm., 9·6 mm. Clear vitreous with the sub-apical marking narrowly brown, costal and sub-costal veins reddish, others, including ambient, brownish-black; basal portions of main veins enclosing M, Cu1, and Cu2, more or less suffused reddish. Posterior, male, average length 14·0 mm., width 8·9 mm.; female, 15·2 mm., 9·6 mm. Clear vitreous, costal and ambient veins black, others reddish-brown, basal half of Cu1 sometimes blackish. Anal area with 3A broadly bordered translucent white, anal cell translucent white with an elongate blackish-brown spot.

LEGS. Generally blackish with pale creamy brown markings; moderately clothed with fine brown short hairs interspersed with longer ones; anterior pair almost wholly blackish, median less so, posterior with proximal of femur and greater portion of tibia creamy-brown becoming darker at distal. Anterior femora with three stout

sharply pointed shining black teeth, proximal longest, distal shortest and close to median. Posterior tibiae with two rows of brown spines, two on the outer row before half way, and four similar on the inner row from just before half way to near distal. Tarsi, anterior, black, terminal claws brownish-yellow; middle, first and second joints black, third black with a yellowish-brown marking, and terminal claws yellowish-black; posterior, first and second joints black, third yellowish-brown to two thirds, apex and terminal claws black. Operculae black, clothed with fine black hairs, interior margins fairly wide apart, edges recurved, interior angles sharply rounded, exterior less so.

Abdomen. Black, sometimes a few scattered golden hairs dorsally from segment two to apical, underside black, fairly densely clothed with black hairs and a few scattered very short golden ones; posterior margins of last six (normally) segments reddish-brown, brightest along lateral expansion of each margin. Tympani translucent dark greyish showing five parallel dark brown lines.

Type. In British Museum (Natural History).

List of Examined Specimens.

In National Museum of Victoria—

Tasmania. 1 ♂, Mt. Wellington, 1.1949, C. Oke; 1 ♂ 1 ♀, 18.1.1915, G. H. Hardy; 4 ♂ ♂, Lake Fenton, 27.12.1951, J. R. Cunningham.

In Australian Museum, Sydney—

Tasmania. 2 ♂ ♂, Mt. Wellington, 18.1.1915, G. H. Hardy.

In Tasmanian Museum, Hobart—

Tasmania. 1 ♂ 1 ♀, Mt. Wellington, 3700 ft., 7.2.1942, J. W. Evans; 1 ♂ 2 ♀ ♀, Mt. Wellington, 4.2.1953, J. R. Cunningham; 1 ♂, 18.1.1915, G. H. Hardy; 1 ♀, 25.1.1947, S. Angel.

In South Australian Museum, Adelaide—

Tasmania. 3 ♂ ♂, Mt. Wellington, 16.1.1915; 1 ♂, 18.1.1915; 1 ♂, 11.2.1917, G. H. Hardy; 1 ♂, 5.1.1918, C. E. Cole.

In Author's Collection—

Tasmania. 11 ♂ ♂ 2 ♀ ♀, Miena, 3400 ft., 28.2 to 1.3.1954, R. Dobson; 2 ♂ ♂, Lake Dobson, 3000 ft., 22.3.1954, L. E. Couchman.

Diemeniana tillyardi Hardy

Diemeniana tillyardi Hardy 1917. *Proc. Roy. Soc. Tas.*: 69.

This interesting species is similar in size and appearance to *D. turneri,* but present records indicate that its distribution is apparently very local and confined to the Cradle Mountain (Tasmania) region. It may easily be distinguished from *turneri* by the larger sub-apical marking on the anterior wings, the more reddish colouration of the wing veins, the reddish banding on the underside of the abdomen, and pale brown edges to the operculae. *D. turneri* is a much blacker looking insect. The sexes are similar, so a description of the male is given.

Average Length. Male, 21·5 mm.; female, no specimen available for measurement.

Head. Not as wide as pronotum, dull black, finely granulate, clothed with fairly long dark brown hairs, a triangular pinkish-brown depressed spot on vertex, on

either side near eyes a similar spot, less depressed. Ocelli reddish vitreous, anterior slightly depressed, very slightly anterior to fore margin of eyes, distance between two posterior slightly greater than between anterior and each posterior. Antennae shining black. Frons uniformly dark brownish-black, rather densely clothed with fairly long dark brown hairs; a pinkish-brown elongate depressed spot extending from summit to just beyond half way, sides broadly pinkish-brown, transverse ridges black, nine in number, interstitial grooves black, slightly duller than ridges. Summit of frons flat, coarsely punctate, median groove wide and shallow. Clypeus black, slightly shining, coarsely punctate, half as long as frons. Labrum brownish-black, slightly shining, planate laterally. Labium brownish-black, slightly shining. Genae black, slightly shining, moderately clothed with pale brown hairs, coarsely punctate, lamellate, bordered exteriorly pinkish-brown, carinate. Eyes opaque brownish-black, orbits fringed beneath, and almost round to anterior margin of pronotum with light greyish-brown hairs.

Thorax. Width 7 mm.; dull black, rather coarsely and irregularly punctate. Pronotum with two wide sulci on each side, these sparsely invested with short golden hairs; anterior margin very narrowly pinkish-brown, a median pinkish-brown longitudinal marking extending from near anterior margin to three quarters; posterior margin broadly pinkish-brown, almost straight. Lateral margins black, carinate, produced at just beyond one third from posterior margin to form a broad flat tooth. Mesonotum dull black, sculptured more finely than pronotum; on each side of the median a triangular pinkish-brown marking dorsally. Cruciform elevation brownish-black, almost smooth, anterior half darker in colour than posterior. Metanotum straight, transverse, light brown, a central dark brown tubercle slightly inclined towards the posterior angle of the cruciform elevation. Beneath, the coxal cavities are narrowly edged pinkish-red.

Wings. Anterior, male, average length, 22·5 mm.; width, 9·2 mm.; female, no specimen available for measurement. Clear vitreous, costal and subcostal veins reddish-brown, others slightly paler reddish-brown as far as the marginal area, then gradually darkening to brown. Ambient vein dark brown from Cu1 A to R2. A brown irregular sub-apical spot broadly bordering cross veins between R3, R4 + 5, and M1, but not reaching R2. Posterior, male, average length, 14 mm.; width, 8·7 mm.; female, no specimen available for measurement. Clear vitreous, veins pinkish-brown, ambient normally from R2 + 3 to Cu1 A dark brown. Vein 2A edged brown on the inner side from half-way to edge of wing, the brown extending round the edge to 3A which is edged translucent white. Anal cell translucent white with a central oblong brown spot. Extreme base of wings orange-brown.

Legs. Yellowish-brown with a pinkish suffusion, moderately clothed with fairly long fine brownish hairs, marked with fairly narrow elongate brownish-black markings. Anterior pair most heavily marked, median less so, posterior least. Anterior femora with three stout shining black teeth faintly tipped brownish, all directed slightly upwards and almost equidistant from one another, the distal and median slightly closer together than the proximal and median. Posterior tibiae with two rows of brown spines, two on the outer row, the first about half way, the other midway between it and distal; four similar on the inner row from one third to three quarters and almost equidistant from one another. Tarsi, anterior, black; middle first and second joints brownish-black; third yellowish-brown with distal half black; posterior first joint black, second brownish-yellow, third brownish-yellow with apex and terminal claws black. Operculae dark brown edged pale brown,

clothed with fine fairly long brown hairs; interior margins wide apart, edges slightly recurved, interior and exterior angles acutely rounded.

ABDOMEN. Deep black with a faint silky lustre, a few scattered silvery hairs mainly on the mid-dorsal of each segment, much denser on the last two and extending to the edges; underside black, punctate, posterior margins of segments broadly reddish-brown, invested with short silvery hairs interspersed with longer fine brown hairs; tympani translucent greyish-brown marked with five radiating darker brownish lines.

HOLOTYPE male and one paratype male in Australian Museum Collection.

LIST OF EXAMINED SPECIMENS.

In Australian Museum, Sydney—

Tasmania. 1 ♂, Cradle Mountain, 27.1.1917, G. H. Hardy. Paratype.

In Tasmanian Museum, Hobart—

Tasmania. 1 ♂, Lake St. Clair, 2.1941, J. W. Evans; 1 ♂, 19.1.1917, G. H. Hardy.

In South Australian Museum, Adelaide—

Tasmania. 1 ♂, Cradle Mountain, no date, Carter and Lea.

Diemeniana (Cicada = Abricta) euronotiana Kirkaldy

Cicada aurata Walker 1850. *List. Hom. Br. Mus.*: 215.
Cicada aurata Atkinson 1885. *Jour. Asiatic Soc. Bengal* 53: 230.
Tibicen auratus Goding and Froggart 1904. *Proc. Linn. Soc. N.S.W.* 29: 606.
Abricta aurata Distant 1906. *Syn. Cat. Hom.* 1: 130.
Abricta aurata Froggatt 1907. *Australian Insects*: 351.
Abricta euronotiana Kirkaldy 1909. *Canad. Ent.*: 391.
Abricta aurata Ashton 1912. *Mem. nat. Mus. Vic.* 4: 24; Pl. IV, fig. g.
Abricta aurata Ashton 1914. *Trans. Roy. Soc. S. Aust.* 38: 349.
Abricta aurata Tillyard 1926. *Insects of Australia and New Zealand*: 161.

This species inhabits open country where it rests on grasses and low bushes at an average height of about 2 ft. from the ground. Its range extends from Barrington Tops, N.S.W., to Tasmania. In Victoria and Tasmania it occurs from near sea level to about 1000 ft.; extending its range northwards it becomes more and more a mountain insect; on the Barrington Tops it is found normally at about 4000 ft. and over. In habits it resembles *D. neboissi,* and its season ranges from December to February. In this revision of the genus *Diemeniana* it has been decided to remove it from *Abricta* and place it under *Diemeniana.* Species of *Abricta* have the anterior wings three times as long as wide, and rest on branches and trunks of trees at heights usually greater than 3 ft. from the ground.

AVERAGE LENGTH. Male, 18·6 mm.; female, 18·2 mm.

HEAD. Slightly wider than pronotum, dull black, finely granulate, clothed dorsally with sparse fine golden hairs interspersed more densely with fairly long blackish ones; a pale yellowish-brown depressed spot on vertex, a similar narrower spot on summit of frons converging and extending back towards the anterior ocellus, another small yellowish-brown spot near each eye. Summit of frons finely punctate, grooved medianally, each half planate and gradually sloping to median. Ocelli red vitreous, anterior depressed, almost in line with anterior margin of pronotum, distance between two posterior slightly greater than between anterior and each posterior. Antennae black. Frons varying shades of yellowish-brown often ranging to dark brown towards

the summit; moderately clothed with fairly long brownish hairs, a median groove extending to clypeus, transverse ridges 9 in number, interstitial grooves darker in colour. Clypeus yellowish-brown, a very small dark brown obscure spot in centre, distal narrowly dark brown, more than half the length of frons. Labium yellowish-brown, apex broadly black. Genae brownish-black, irregularly sculptured, clothed with moderately long brownish hairs, exterior edges finely carinate, lower half of carinae yellowish-brown. Eyes pale yellowish-brown, orbits fringed beneath with fairly long light brown hairs and round to anterior margin of pronotum.

THORAX. Width 7 mm., black, finely punctate, sparsely dusted with fine short golden hairs. Pronotum with two sulci on each side, anterior margin pale yellowish-brown; a median pale yellowish-brown marking extending to half way then curving outwards towards the posterior margin. In some specimens a dark brown spot occurs posteriorly in this yellowish-brown marking. Edges broadly yellowish-brown, carinate, produced to form a rather sharp tooth just posterior to half way. Posterior margin very prominent, yellowish-brown, almost transversely straight. Mesonotum black, extremely finely punctate, on each side of median a triangular yellowish-brown "H-like" dorsal patch; the posterior portion of the black area thus enclosed being dusted with fine golden hairs. Cruciform elevation dull yellowish-brown with a dark brown median linear marking, sparsely dusted with short golden and a few longer fine brown hairs. Metanotum dull yellowish-brown, almost transversely straight and with a central black tipped tubercle. Beneath, the thorax is pale yellowish-brown with black markings, and fairly densely clothed with fine rather long pale yellowish-brown hairs.

WINGS. Anterior, average length, male, 21·4 mm., width, 9·0 mm.; female, 20·3 mm., 8·5 mm. Clear vitreous, costal and sub-costal veins reddish, others, including ambient, reddish as far as outer discal area, black in marginal area. A brownish-black irregular sub-apical spot broadly bordering cross veins between R3, R4 + 5, and M1. Posterior, average length, male 11·1 mm, width, 8·5 mm.; female, 11·7 mm., 7·8 mm. Clear vitreous veins pale yellowish-brown excepting ambient which is black; 2A and 3A narrowly bordered brown. 2A greatest distally, anal cell edged pink adjoining abdomen and with an opaque brown central spot. Extreme bases of wings pinkish-red.

LEGS. Pale yellowish-brown with black markings which are most extensive on the anterior pair, about equal in extent on the median and posterior. Anterior femora with three shining black teeth directed outwards and slightly upwards; proximal at half way and about twice as large as the others, median slightly larger than distal, the latter with a very small tooth near its base adjoining the tibia. Median and distal close together and situated medianally on posterior half of femur. Posterior tibiae with two rows of brown spines, two on the outer row, first about half way, second beyond half way from first to distal, normally four (rarely five) on the inner row, first at half way, others equidistant from one another to distal. Tarsi, anterior, first and second joints black, third black with base yellowish; middle, first joint black, second and third yellowish, the latter with apex and terminal claws black. Operculae pale yellowish-brown, clothed with very fine pale brown hairs, interior margins wide apart, edges abruptly recurved, interior angles acute, exterior openly rounded.

ABDOMEN. Deep black, a few scattered short golden hairs dorsally on each segment, more laterally on the posterior margins of each segment. Apical segments usually wholly dusted with golden hairs. Underside pale yellowish-brown clothed with golden hairs interspersed with longer pale brown hairs; narrowly black along intersegmental margins especially on the first segment which has a median black

spot. Lateral margins of segments with black markings and clothed with fine golden hairs. Tympani translucent smoky brown showing five darker irregular markings.

TYPE. In British Museum (Natural History).

LIST OF EXAMINED SPECIMENS.

In National Museum of Victoria—

New South Wales. 1 ♂ 1 ♀, Barrington Tops, 5000 ft., 13.12.1921, A. N. Burns; 5 ♂ ♂, Tubrabucca, 4500 ft., 17.11.1953, A. Neboiss; 1 ♂, Blue Gum Knob, Chichester, 3.2.1921, Pres. by N. Cayley; 1 ♂, Burrawong, 7.1.1951, R. Dobson.

Victoria. 1 ♂, Victoria, 16.1.1909, Pres. S. W. Fulton; 1 ♂, Meeniyan, 1896, T.K. (T. Kershaw); 3 ♂ ♂, Wilson's Promontory, 12.1905; 2 ♂ ♂, 30.12.1920, J. Kershaw; 3 ♀ ♀, Moe, 23.12.1898; 1 ♀, 2.1899, W.K. (W. Kershaw); 1 ♀, Traralgon, no date, Miss J. Galbraith; 1 ♂, Yarragon, 12.1892, J. A. Kershaw; 2 ♂ ♂, Kinglake, 2.12.1945?; 5 ♂ ♂, Mt. Buffalo, 4500 ft., 13.1.1955, A. Neboiss; 1 ♂, Buxton, 7.12.1954, A. Neboiss; 1 ♂, Yarram, 12.1892, J. A. Kershaw.

Tasmania. 1 ♂, Wedge Bay, 8.1.1914; 1 ♀, 28.12.1913, G. H. Hardy; 1 ♀, Tasmania, no date, named by F. Walker; 2 ♂ ♂, Launceston, 1.1.1934, R. T. M. Pescott.

In Australian Museum, Sydney—

Tasmania. 1 ♂, Wedge Bay, 7.1.1914; 1 ♂, Geeveston, 24.12.1914, G. H. Hardy.

In Author's Collection—

New South Wales. 2 ♂ ♂, Barrington Tops, 5000 ft., 16.12.1921, A. N. Burns; 8 ♂ ♂, Tubrabucca, 4500 ft., 17.11.1953, A. Neboiss.

Victoria. 1 ♂, Yinnar, 2.1.1953, A. L. Brown; 1 ♂, 16.12.1948; 1 ♂, 5.1.1952, J. Courtenay; 3 ♂ ♂, Driffield, 3.12.1949, J. Courtenay; 1 ♂, 27.12.1951, A. L. Brown; 2 ♂ ♂, St. Andrews North, 1.1.1952, A. N. Burns; 2 ♂ ♂, Kinglake, 2.12.1954, A. N. Burns; 1 ♂ 1 ♀, 14.12.1946, 2 ♂ ♂, 30.1.1946, C. Langley; 3 ♂ ♂, Kallista, 3.12.1950, 2 ♂ ♂ 1 ♀, 24.12.1946, 1 ♂, Belgrave, 21.12.1930, 2 ♂ ♂, Cockatoo, 28.12.1921, 3 ♂ ♂, Heathmont, 2.11.1930, A. N. Burns; 1 ♂, Tarrawarra, 3.1.1954, 2 ♂ ♂, Wilson's Promontory, 31.1.1954, A. Neboiss.

Tasmania. 6 ♂ ♂, Kingston, 1.1.1948, 1 ♂, 17.2.1948, 1 ♂, 3.1.1947, J. R. Cunningham; 2 ♂ ♂ 1 ♀, Lindisfarne, 3.1.1954, L. E. Couchman.

Diemeniana tasmani Kirkaldy

Cicada coleoptrata Walker 1850. *List. Hom. Br. Mus.*: 223.
Tibicen coleoptrata Stal 1862. *Ofv. Vet.-Ak. Forh.*: 485.
Tibicen coleoptratus Goding and Froggatt 1904. *Proc. Linn. Soc. N.S.W.* 29: 608.
Diemeniana coleoptrata Distant 1905. *Ann. Mag. nat. Hist.* (7) 16: 206.
Diemeniana coleoptrata Distant 1906. *Syn. Cat. Hom.* 1: 146.
Diemeniana tasmani Kirkaldy 1909. *Canad. Ent.* 41: 290, n.n. for *coleoptrata* preocc. Walker.
Diemeniana coleoptrata Ashton 1912. *Mem. nat. Mus. Vic.* 4: 24; Pl. IV, fig. d.

This Cicada occurs from late December until mid-February, and is always associated with open country bordering river or creek flats where specimens may

be found resting on grass stems, usually in tussocks, or rarely on low growing shrubs at an average height of 18 in. from the ground. The sexes are similar so a description is given of the male.

Average Length. Male, 17·1 mm.; female, 15·5 mm.

Head. Dull black coarsely granulate, moderately invested with very short golden hairs; a small depressed orange-brown marking on vertex and an obscure similar marking on summit of frons and extending down its front to about half way. Summit of frons planate, punctate, widely and shallowly grooved medianally. Ocelli garnet vitreous, anterior in line with foremargin of eyes, distance between two posterior slightly greater than that between the anterior and each posterior. Antennae dull brownish-black. Frons brownish-black, a median groove from summit to base, transverse ridges 9 in number, interstitial grooves with very fine golden hairs. Clypeus pale brown, half as long as frons, a small raised black spot in the centre. Labrum pale brown. Labium pale brown, apex slightly darker. Genae dark brown, very finely sculptured, strongly produced laterally, sparsely invested with short golden hairs. Eyes dark brown, orbits fringed below with long light brown hairs which extend round to the anterior margin of the pronotum.

Thorax. Width, 5 mm., brownish-black, coarsely granulate, pronotum with two fairly deep sulci, the outer extending as far back as the posterior margin, the other meeting its opposite in the centre at the median longitudional groove; sometimes two obscure light brown patches, one on each side of the median groove and adjoining the posterior margin, edges strongly carinate, light brown, produced to form a tooth at approximately one third from the posterior margin. Mesonotum brownish-black, dusted laterally with very fine golden hairs, more densely dorsally just anterior to the cruciform elevation; more finely and less granulate than pronotum; a light brown elongate triangular patch on either side of the median, edges light brown. Cruciform elevation brownish-black, extreme apex blackish. Posterior margin sharply carinate, yellowish-brown. Metanotum brown, dusted with golden hairs, transversely straight medianally then curving slightly forwards to the base of the posterior wings.

Wings. Anterior, average length, male, 15·4 mm., width, 6 mm.; female, 14·8 mm., 5·8 mm. Infuscate pale brown, costal and sub-costal veins reddish-brown, others, including ambient, brown. A sub-apical dark brown patch bordering cross veins from R1 to M1, variable in width in individuals. Posterior, average length, male, 10·0 mm., width, 5·9; female, 9·8 mm., 5·3 mm. Faintly infuscate pale brown, veins slightly tinged pinkish. Anal area almost clear hyaline.

Legs. Generally light brown with elongate dull black markings; femora of anterior pair clothed with short pale brown hairs, three stout black teeth along the inner margin, the proximal longest and directed upwards, median and distal about equal in size, directed outwards. Posterior tibiae with two rows of black spines, two between half way and distal on the outer row, three similar and similarly placed on the inner row. Tarsi, anterior, black; middle, first and second joints black, third yellowish-brown to half way, distal half and terminal claws black; posterior, first joint black, second and third yellowish-brown, the latter with apex and terminal claws black. Operculae pale yellowish-brown, bases dull blackish-brown, dusted lightly with very short golden hairs, interior margins wide apart, exterior and interior angles rounded.

Abdomen. Brownish-black, extremely finely punctate, posterior margins of last five segments brown, last two (rarely three) segments dusted dorsally with golden

hairs. Underside brown, dusted with fine pale golden hairs, median areas of segments and anterior portions of lateral expansions blackish. Tympani translucent brown showing five almost parallel darker irregular lines.

TYPE. In British Museum (Natural History).

LIST OF EXAMINED SPECIMENS.

In National Museum of Victoria—

New South Wales. 1 ♀, named by F. Walker, 1873.

Victoria. 1 ♂, Launching Place, 12.1.1918, F. P. Spry; 2 ♂ ♂, Mt. Feathertop, 10.1.1944, C. Oke; 1 ♂ 1 ♀, Fernshaw, no date, from Kershaw; 1 ♂ 1 ♀, Gippsland, no data; 9 ♂ ♂, Alexandra, 1.1956, E. Matheson.

In Australian Museum, Sydney—

Victoria. 1 ♀, Woori Yallock, 3.2.1907, F. P. Spry.

In Tasmanian Museum, Hobart—

Tasmania. 1 ♂ (freshly emerged specimen), Tasmania, no data.

In Author's Collection—

Victoria. 1 ♂ 1 ♀, Tarrawarra, 3.1.1932, 14 ♂ ♂, Woori Yallock, 30.12.1947, A. N. Burns; 1 ♂, Alexandra, 13.1.1956, E. Matheson; 11 ♂ ♂, Steeles Creek, 6.1.1954, 1 ♂, Healesville, 7.2.1954, A. Neboiss.

Diemeniana neboissi sp. nov.

This interesting species inhabits open country where it rests on grass stems and sometimes low bushes at a height of not more than 3 ft. from the ground. It occurs during January and February. The sexes are similar so a description of the male is given.

AVERAGE LENGTH. Male, 18·8 mm., female, 19·0 mm.

HEAD. Almost as wide as pronotum, dull black, coarsely granulate, sparsely clothed with fine golden pubescence; a pale brown linear marking on summit of frons which extends down the front to half way, another slightly paler deeply depressed spot on vertex ending acutely between the posterior ocelli. Ocelli pinkish-red vitreous, anterior depressed and in line with fore-margin of eyes, distance between two posterior slightly greater than that between anterior and each posterior. Antennae dark brownish-black. Frons black, dusted with very short golden hairs, more densely in interstitial grooves. A pale brown central marking extending beyond the summit to half way down front, transverse ridges black, 9 in number, interstitial grooves brownish-black. Summit of frons coarsely punctate, weakly grooved medianally, each half planate and sloping gradially towards median. Clypeus pale brown with a very small dark brown central marking; almost two thirds the length of the frons. Labrum pale brown, a faint dark brown line on each side. Labium pale brown, extreme apex brownish-black. Genae brownish-black, outer edges finely and sharply carinate. Eyes greyish-brown, orbits lightly fringed with golden hairs beneath, and round to anterior margin of pronotum.

THORAX. Width, 7 mm., dull black, very finely punctate, dusted with very short golden hairs. Pronotum with two sulci on each side, median groove pale brown from head to half way where it meets the first sulcus; the second almost reaching the posterior margin. Extreme edges of pronotum pale brown, strongly carinate, pro-

duced medianally to form a short tooth. Posterior margin transversely straight, brownish-yellow. Metanotum black, finely punctate, dusted sparsely anteriorly, more densely posteriorly, with very short fine golden hairs; a raised pale yellowish-brown elongate longitudional spot on each side of the median extending from the anterior margin to beyond half way. Cruciform elevation yellowish-brown, apex tipped dark brown. Apices of posterior ridge and exterior angle dark brown. Metanotum ridged, yellowish-brown, almost transversely straight, and with a small median slightly darker brown tubercle.

WINGS. Anterior, average length, male, 19·6 mm., width, 8·1 mm.; female, 19·0 mm., 8·0 mm. Pale hyaline brown gradually darkening towards the base; costal and sub-costal veins reddish-brown, others, including ambient, pale brown; sub-apical spot dark brown and widely bordering cross veins from R1 to M1. Posterior, average length, male, 12·4 mm., width, 7·7 mm.; female, 13·0 mm., 8·0 mm. Almost clear vitreous, gradually becoming very pale hyaline brown from near half way towards base. All veins pale yellowish-brown, 2A and 3A bordered opaque whitish.

LEGS. Dusted with very short golden hairs interspersed with fine and longer brownish ones, pale yellowish-brown with black markings, greatest on the anterior pair, about equal in extent on median and posterior pairs on which they are restricted to coxae and femora. Anterior femora with three black teeth, the proximal at half way being the largest and directed slightly upwards, median slightly larger than distal, these close together medianally between the proximal and tibia. Posterior tibiae with two rows of dark brown spines, two on the outer row, the first half way, the other median to proximal; three on the inner row, the first at half way, the other two equidistant from one another. Tarsi, anterior, first and second joints black, third yellowish to half way, distal half and terminal claws black; middle, first joint black, second and third yellowish, apex and terminal claws of latter, black; posterior, first joint black, second and third yellowish, apex and terminal claws of the latter, black. Operculae pale yellowish-brown, faintly dusted with extremely fine short golden hairs; interior margins not very wide apart, edges weakly recurved, interior angles acute, exterior broadly rounded.

ABDOMEN. Dull black, dorso-median area of first two or three segments dusted lightly with fine short golden hairs; posterior margin of each segment broadly orange-brown. Underside pale yellowish-brown, faintly and irregularly suffused dark brown, dusted with fine short golden hairs; a black central patch on second segment, usually small dull black patches on the last four segments. Tympani pale greyish-brown, showing five bi-lineate dark brown irregular markings.

HOLOTYPE male, four paratype males and one paratype female in the author's collection; allotype female and 18 paratype males in National Museum, one paratype male in Australian Museum.

LIST OF EXAMINED SPECIMENS.

In National Museum of Victoria—

Victoria. 7 ♂ ♂, Tawonga, 28.1.1957, 1 ♂, Biggara, 29.1.1957, 9 ♂ ♂, Towong, 29.1.1957, A. Neboiss; 1 ♀, Towong, 22.1.1950, E. Matheson.

In Author's Collection—

Victoria. 1 ♂, Tawonga, 28.1.1957, A. Neboiss; 4 ♂ ♂ 1 ♀, Corryong, 12.1.1954, E. Matheson.

Diemeniana richesi Distant

Diemeniana richesi Distant 1913. *Ann. Mag, nat. Hist.* (8) 12: 488.

Apparently very little is known about this species which was first taken at Cooma, N.S.W., in 1912. I am indebted to Mr. R. J. Izzard of the British Museum (Natural History) for his kindness in supplying the description and photograph of this Cicada. I do not know of any specimens of this species occurring in any Australian collection.

LENGTH. Male, 18 mm.; female ?.

HEAD. Almost as wide as pronotum, black with scattered golden pubescence, similar in sculpture to *D. tasmani*. Ocelli, red vitreous, equidistant from eyes, distance between two posterior slightly greater than between anterior and each posterior. Antennae, basal segment black, other segments missing from specimen. Frons, black, transverse ridges nine in number, not pitted but very faintly punctate, invested with short golden pubescence; interstitial grooves black. Clypeus, black with golden pubescence, triangular in shape, half as long as frons. Labrum dark brown with short black stripes. Labium, golden brown, apex black. Genae, black with golden pubescence, lunulate in shape, attenuated at clypeus, narrowly margined yellow.

THORAX. Width, 7 mm., black; underside yellow, coxal cavities margined black. Pronotum with scattered golden pubescence, lateral and posterior margins brownish-yellow, two sulci on each side, the anterior most pronounced and meeting at the median. Lateral margins carinate, produced to form a rather sharply pointed tooth posteriorly to half way. Mesonotum black margined brownish-yellow; two elongate median yellow bands extending to posterior margin of pronotum. Cruciform elevation yellow. Metanotum black, ridged transversely at median then curving slightly forwards at each side towards base of posterior wings.

WINGS. Anterior, length, male, 17 mm., width, 7 mm.; female, ?. Infuscate, all veins brown, a fuscous patch in cell between M4 and Cu1, sub-apical spot fuscous, widely bordering cross veins between M1 and R3. Posterior length, male, 11 mm., width, 5 mm.; female, ?. Clear vitreous, veins brown, a small almost central fuscous spot in angle at basal angle of M1 + 2 and M3 + 4; veins 2A and 3A bordered opaque whitish.

LEGS. Anterior and middle pair golden yellow with fuscous elongate markings, tarsi blackish-brown; middle pair with all joints golden yellow including tarsi with exception of apical joint which is black; posterior with coxae and trochanters fuscous, femur golden yellow, tibia golden yellow with extreme apex black, tarsi yellow excepting apical joint which is black. Anterior femora with three blackish-brown spines, the proximal at half way, long and inclined forwards; median and distal shorter and close together, also inclined forwards. Posterior tibiae with two rows of blackish spines, six in all, the proximal in each row at half way. Operculae with interior margins fairly wide apart, golden yellow excepting for a narrow black basal margin broken by a greyish-white spot; lateral margins black in basal half. Interior angles broadly rounded, exterior acutely so.

ABDOMEN. Black, segments narrowly margined brownish-yellow posteriorly invested with sparse silvery pubescence. Ventral surface yellow excepting for a basal black margin and a series of black fasciae medianally on each segment and a black stripe on the seventh connexivum. Genital capsule brownish, sparsely golden pubescent. Tympani translucent whitish-yellow with five brown ridges.

TYPE. In British Museum (Natural History).

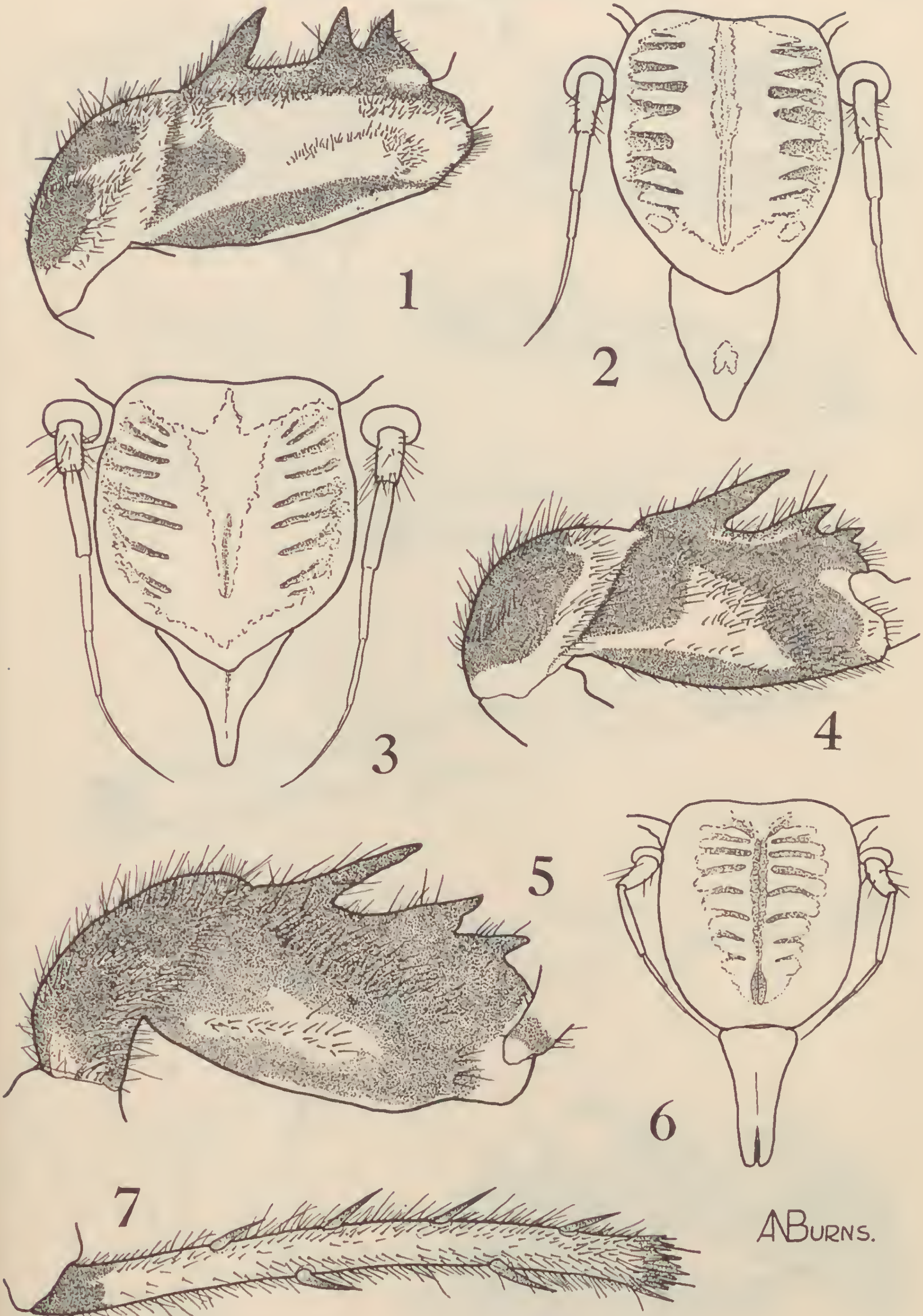

Fig. 1

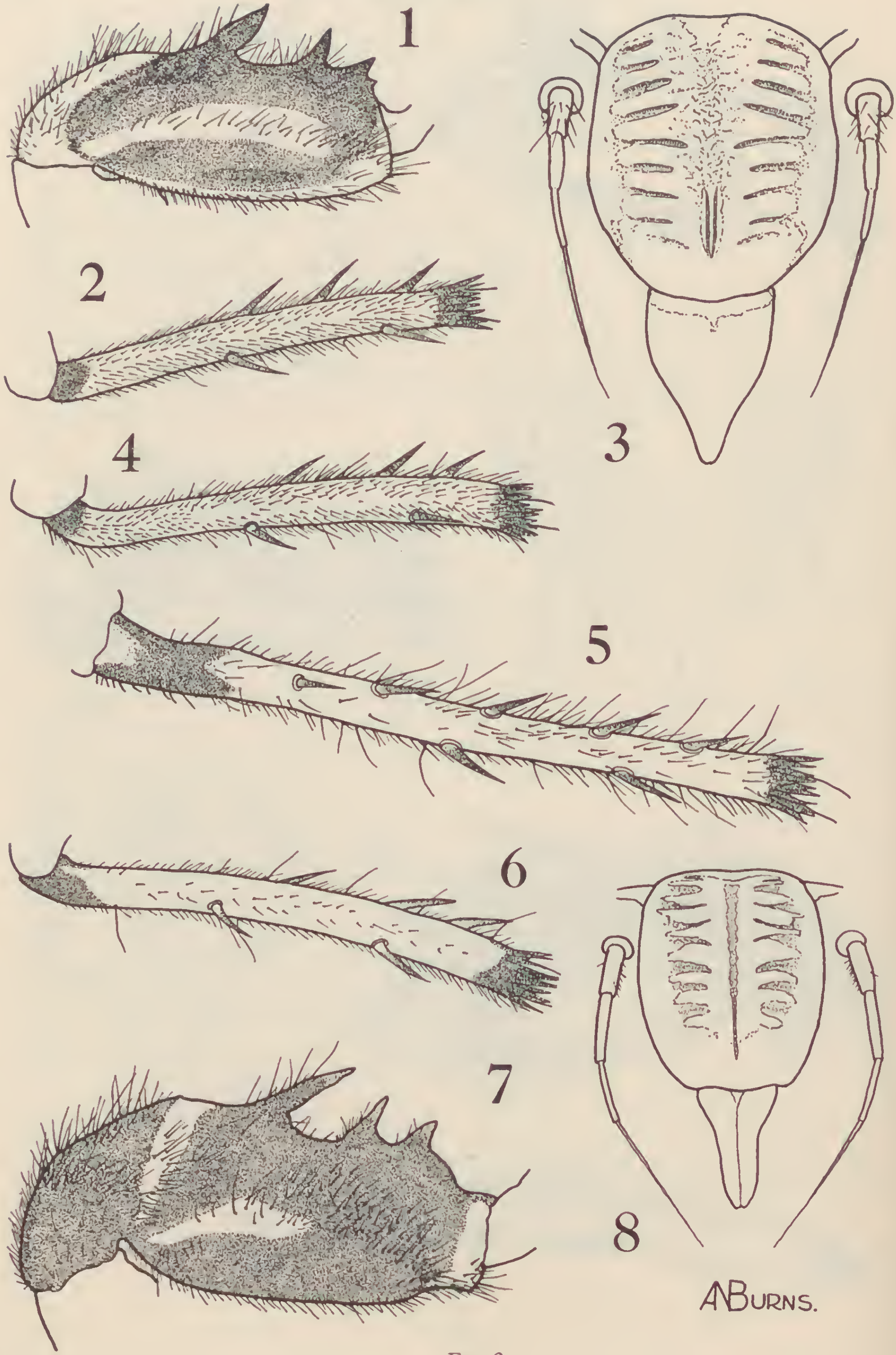

Fig. 2

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———, 1913. *Ann. Mag, nat. Hist.* (8) 12: 488.
———, 1914. ibid. 14: 325.
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HARDY, G. H., 1917. *Pap. Proc. Roy. Soc. Tas.* for 1916: 69.
TILLYARD, R. J., 1926. *Insects of Australia and New Zealand*: 161.
WALKER, F., 1850. *List. Hom. Br. Mus.* 1-3: 215, 223.

Explanation of Figures

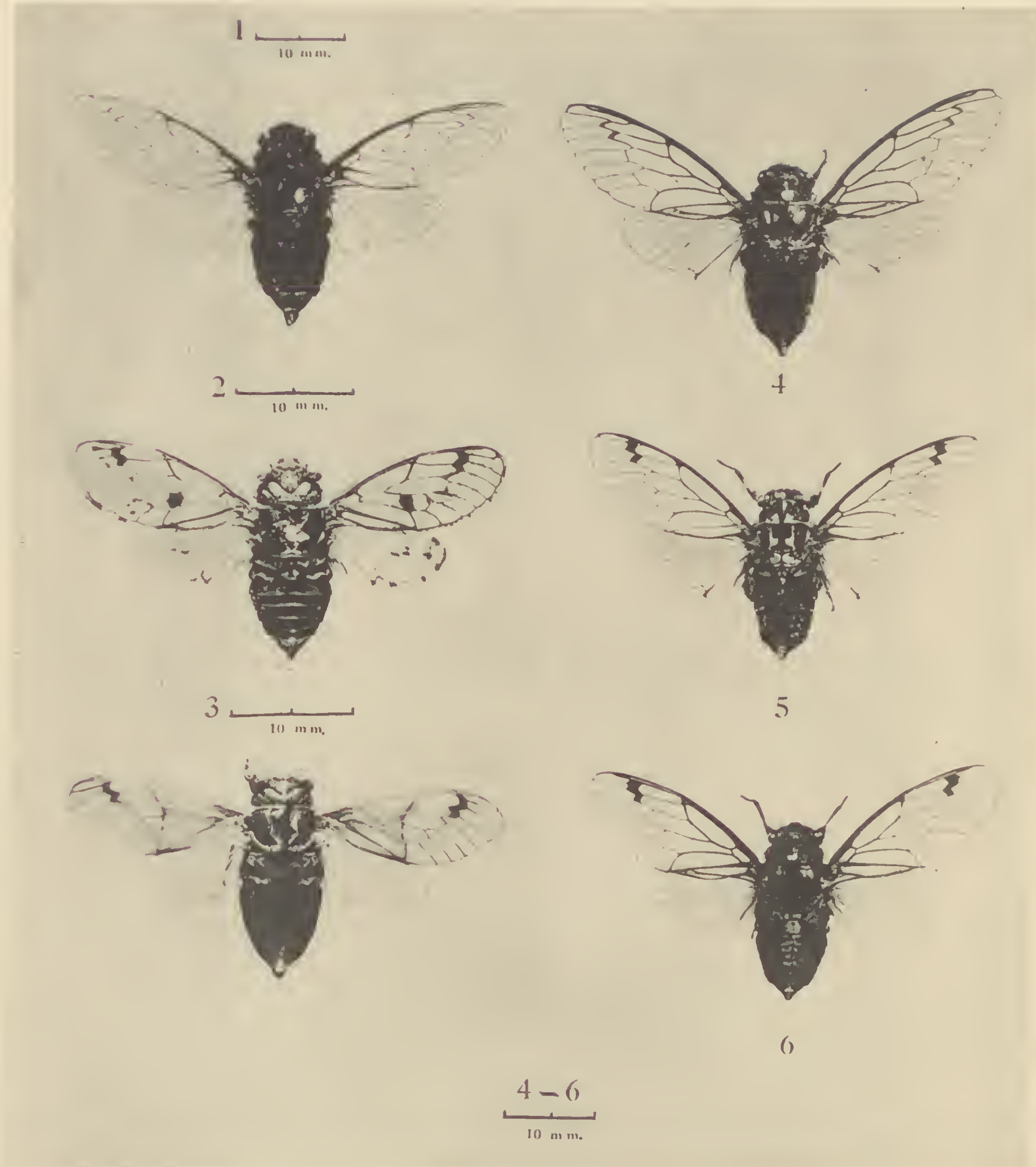
FIG. 1.—(1) Anterior femur *Diemeniana neboissi* ♂. (2) Frons *Diemeniana neboissi* ♂. (3) Frons *Diemeniana tillyardi* ♂. (4) Anterior femur *Diemeniana euronotiana* ♂. (5) Anterior femur *Diemeniana tillyardi* ♂. (6) Frons *Diemeniana euronotiana* ♂. (7) Posterior tibia *Diemeniana tillyardi* ♂.

FIG. 2.—(1) Anterior femur *Diemeniana tasmani* ♂. (2) Posterior tibia *Diemeniana tasmani* ♂. (3) Frons *Diemeniana turneri* ♂. (4) Posterior tibia *Diemeniana neboissi* ♂ . (5) Posterior tibia *Diemeniana turneri* ♂. (6) Posterior tibia *Diemeniana euronotiana* ♂. (7) Anterior femur *Diemeniana turneri* ♂. (8) Frons *Diemeniana tasmani* ♂.

Explanation of Plate

PLATE XXV

Fig. 1.—*Diemeniana turneri* Distant ♂.
Fig. 2.—*Diemeniana richesi* Distant ♂.
Fig. 3.—*Diemeniana tasmani* Kirkaldy ♂.
Fig. 4.—*Diemeniana tillyardi* Hardy ♂.
Fig. 5.—*Diemeniana euronotiana* Kirkaldy ♂.
Fig. 6.—*Diemeniana neboissi* sp. nov. ♂.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7

LARVA AND PUPA OF AN AUSTRALIAN LIMNEPHILID (TRICHOPTERA)

By Arturs Neboiss, M.Sc., F.R.E.S.*

[Read 12 December 1957]

Abstract

The larva and pupa of *Archaeophylax ochreus* Mosely, the only known species of the family Limnephilidae, is described and figured. A short account of the habitat is also given. This species is recorded for the first time in Victoria.

Introduction

The discovery of the larva and pupa of *Archaeophylax ochreus* Mosely is of particular interest, because as far as is known, it is the only species of the family Limnephilidae represented in Australia. Originally this species was known from Tasmania and New South Wales, indicating that it might also be found in Victorian mountain streams. When collecting on Bogong High Plains in north-eastern Victoria, January to March 1957, the author was successful in not only obtaining adult specimens, but also in correlating larval and pupal stages with the adults, and learning more about the type of streams in which they live.

Habitat

Adult specimens were found near streams only above 4,800 ft., indicating their partiality to temperate climatic conditions. This altitude is near the tree line in the Victorian Alps, and most specimens were collected in open forest areas (Pl. XXVI, fig. 2), whereas no specimens were collected in dense scrub. Larvae were found in calm pools of otherwise rapidly flowing small, stony streams with partly sandy beds. They live under stones in small or large groups (Pl. XXVI, fig. 1); when fully grown they attach their cases to the under surfaces of stones, and partially seal the case openings before pupating.

During the last two weeks in January 1957 large areas of snow still remained on the higher altitudes in the Hotham-Bogong district, in spite of the day temperatures rising up to 24° C. The melting snow kept water temperature in streams down to 14° or 15° C., apparently below the average for the same time in other years, thus slowing the emergence of adults. At this time only larvae, with the exception of few pupae, were collected. Mosely and Kimmins (1953) gave January 1 and 27 as collecting dates for specimens from Mt. Kosciusko district only about fify miles away. The author, when collecting in Hotham-Bogong district between March 20 and 30, obtained a number of adults, but on searching the breeding grounds discovered that most of the cases contained pupae about to emerge. However, only a small number had fully grown larvae, or were empty; the latter indicated that emergence had started only shortly before and that most adults would be emerging within the following two weeks, therefore being about two months later than earlier records. At this time the water temperature had risen to 19° or 20° C. and all snow from higher altitudes had disappeared. The above observations demonstrated the important effect of seasonal weather conditions on the time of emergence of mountain caddis flies in Victoria.

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Description

Case. Cylindrical, straight or slightly bent, consists of small pebbles 2 to 4 mm. in diameter, placed without any definite arrangement. Two larval cases are known to the author consisting of vegetable debris, cut in small pieces of approximately the same size as the pebbles used by other specimens. Posterior end only slightly narrowed. Inside covered with fine silken lining. When pupating, both ends of the case are partially sealed leaving a small irregular opening. Length up to 22 mm.; width up to 7 mm.

Larva. Eruciform, cylindrical, head orthocentrous. Pronotum sclerotized, mesonotum with sclerotized central portion, metanotum with small sclerotized patches. Length up to 21 mm.

Head elongate, sparsely covered with bristles as shown in Fig. 1; almost uniformly yellowish brown with the exception of a paler triangular marking at the centre of clypeus slightly above the eyes, and two irregular patches at the widening part of clypeus. Irregular pattern of oval spots are on the aboral part of genae and the narrow part of clypeus. Eyes distinct in light coloured areas. Antennae short, located a short distance below the eyes. Gular sclerite (Fig. 2) pointed aborally. Mandibles black, broad with four blunt teeth on the apical margin, a brush of bristles located at center of inner margin, and two bristles at the exterior aboral margin.

Thorax (Fig. 5). Pronotum sclerotized, yellowish brown, posterior margin dark brown, median line paler, bristles arranged along the anterior margin and again across the middle of pronotum. Mesonotum sclerotized in its central portion only, sclerotized part with darker posterior margin and two dark unequal sized patches laterally, median line pale, comparatively wide. Metanotum with sclerotized patches, each bearing few bristles. Prosternal horn present.

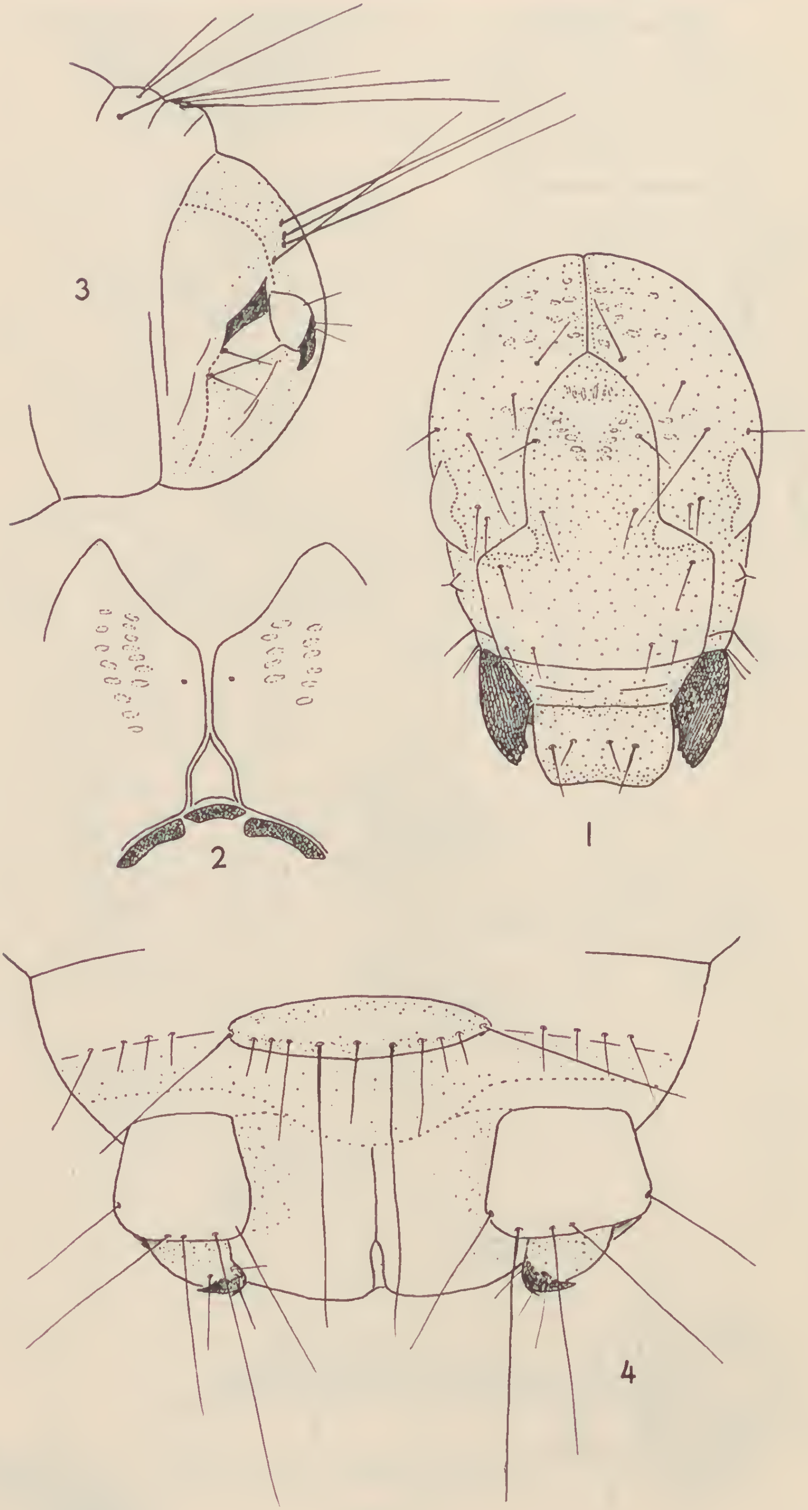
Prothoracic legs (Fig. 10) slightly shorter than the meso- and metathoracic legs; coxa and femur thickened, the latter with a row of scattered bristles along the dorsal edge, tibia with short spines along the ventral edge, the distal one being the longest. Meso- and metathoracic legs (Figs. 11 and 12) very similar except that the mesothoracic legs are more robust.

Abdomen cylindrical, pale yellow or whitish, segments separated by shallow indistinct grooves. Lateral line extends from third to eighth segment. A pair of lateral protuberances on first abdominal segment; dorsal protuberance absent. Ninth abdominal segment with elongate oval sclerite on which a row of bristles is located along the posterior margin, four of the bristles being longer and more distinct, the shorter ones are grouped between as shown in Fig. 4. Anal claws with an additional hook. Gills arranged in large groups on anterior segments, decreasing in size and number towards posterior end of abdomen.

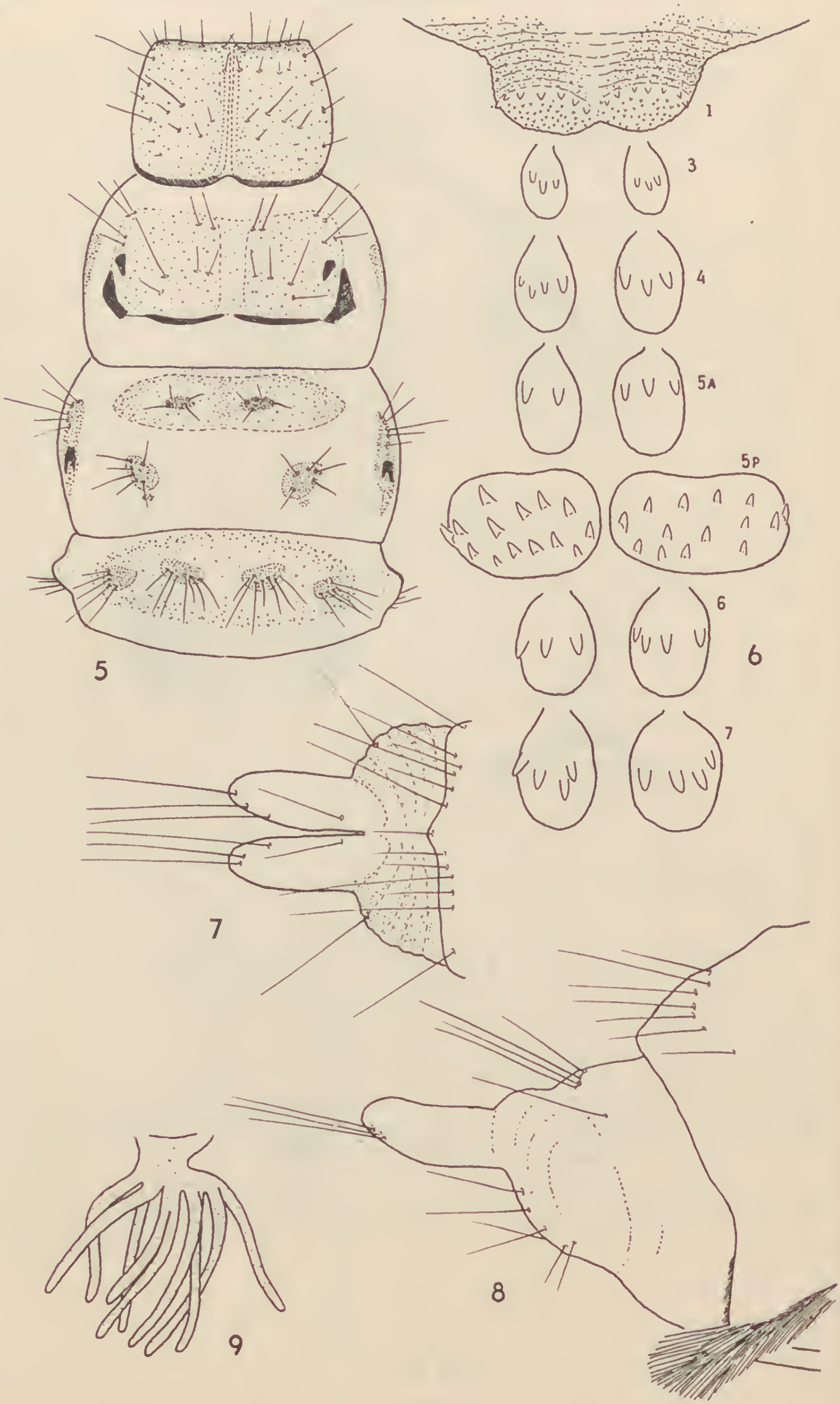
Pupa. Pale yellowish, ninth segment darker, anal processes yellowish brown. Length up to 20 mm., male pupae usually smaller.

Head sparsely covered with erect bristles arranged as follows: two between the antennae, four in centre of forehead, two on each side between clypeus and eye, four pairs on clypeus. A tuft of bristles at the base of each antenna just above the eye, one to three separate bristles on dorsal side of first antennal segment, and a tuft of bristles on the second segment. Mandibles (Fig. 13) strong, somewhat triangular, pointed, with a pair of unequal sized bristles near the base. Antennae are normally kept parallel to the body, and extend posteriorly as far as seventh to ninth segment.

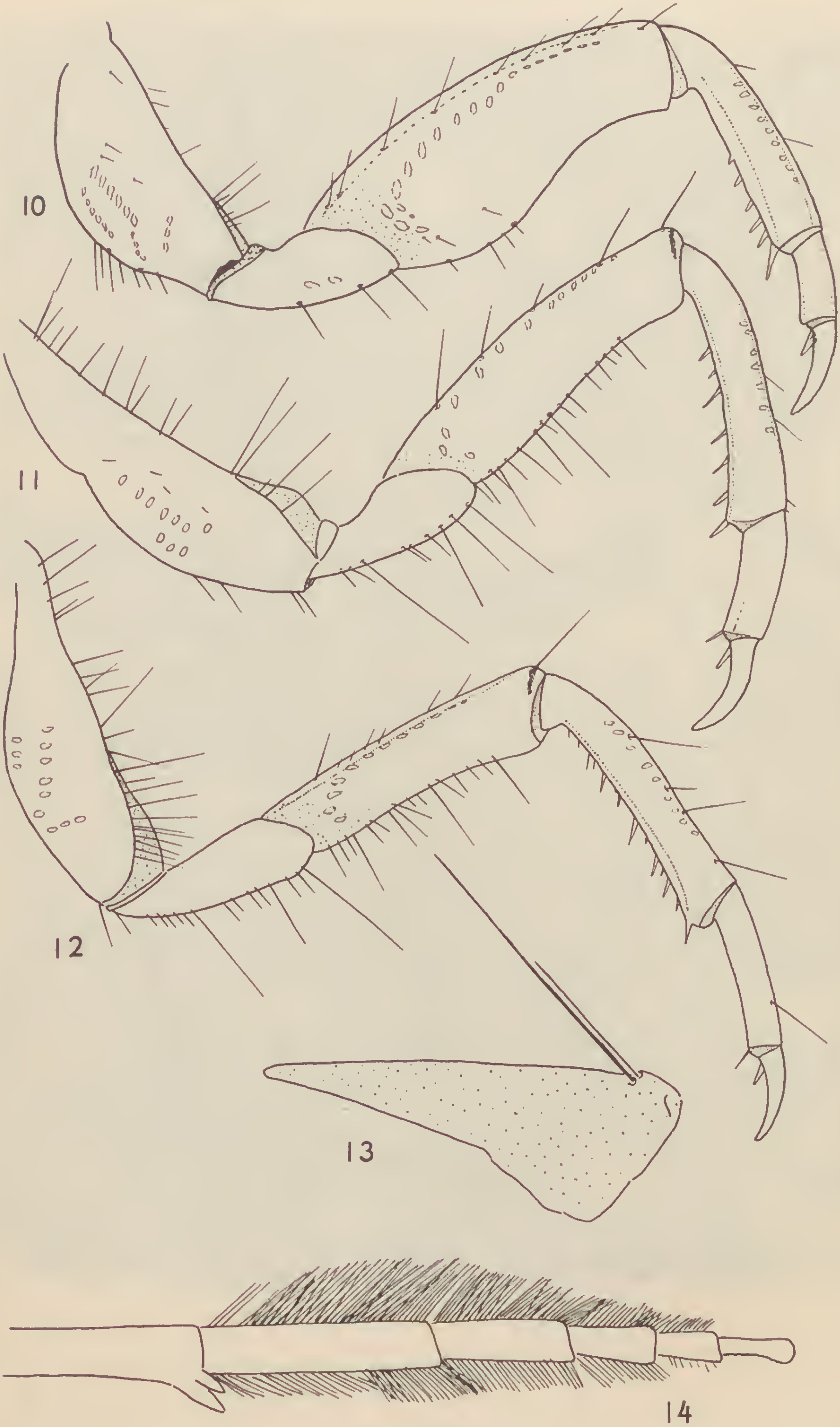
Thorax. Pronotum with two pairs of fine bristles, mesonotum with three pairs, metanotum with three pairs of bristles as well as a pair of sclerotized patches on the pasterior margin.



Figs. 1-4



FIGS. 5-9



FIGS. 10-14

Coxae of prothoracic and mesothoracic legs with patch of bristles. Tarsal joints of mesothoracic legs (Fig. 14) covered on both sides with a row of swimming hairs. Metathoracic legs simple.

Abdomen somewhat cylindrical, sixth and seventh segment being the widest. First segment with sclerotized dorsal plate, elevated posteriorly and ending in a bilobed hook plate (Fig. 6 (1)). Second segment without any kind of hook plates; third to seventh segments with flat hook plates as shown in Fig. 6; fifth segment with two pairs—anterior pair (5A) with two to four hooks directed posteriorly, and posterior pair (5P) with irregularly distributed hooks directed anteriorly. A pair of fine yellowish brown longitudinal lines on dorsal surface of second to eight segments. Lateral line begins at the middle of fourth segment, continues towards the eight segment where both lateral lines almost join on the ventral surface.

Dorsal gills on second to fifth segments; those of anterior segments in larger groups, the posterior ones in groups to two or three. Ventral gills on second to seventh segment; first and last pairs in groups to two or three, others larger.

Male and female sexes are separable in pupae. Just ventral to the anal processes in the male some details of external genitalia are indicated by two lateral lobes and an oval median swelling. The same area ventral to the anal processes in females does not show any such details.

Material Examined

Falls Creek Ski Village, 4,900 ft., 26 March 1957 (adults only); Mt. McKay area, 5,500 ft., 26 March 1957 (adults, larvae and pupae); Mt. Hotham area (Whisky Flat), 5,200 ft., 1 February 1957 (larvae and pupae); 27 March 1957 (also adults).

Larva and pupa described from specimens collected near Mt. McKay, now in the National Museum of Victoria collection; other specimens in C.S.I.R.O. Division of Entomology collection at Canberra, and National Museum of Victoria.

Reference

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Explanation of Figures

Fig. 1.—Larval head from front.
Fig. 2.—Gular sclerite.
Fig. 3.—Posterior abdominal segment lateral.
Fig. 4.—Posterior abdominal segment dorsal.

Fig. 5.—Thoracic and first abdominal segments of larva, dorsal.
Fig. 6.—Pupal hook plates, numbers indicating abdominal segments.
Fig. 7.—Apical processes of pupa dorsal.
Fig. 8.—Apical processes of pupa lateral.
Fig. 9.—Dorsal gill of pupa.

Fig. 10.—Prothoracic leg of larva.
Fig. 11.—Mesothoracic leg of larva.
Fig. 12.—Metathoracic leg of larva.
Fig. 13.—Mandible of pupa.
Fig. 14.—Tarsal joints of pupal mesothoracic leg with swimming hairs.

Explanation of Plate

Plate XXVI

(Photographs by the author)

Fig. 1.—Group of cases on the underside of a stone.
Fig. 2.—Stream at Hotham Heights; calm water pool in foreground.

1

2

8

GENUS *HAPATESUS* FROM THE AUSTRO-MALAYAN SUB-REGION (COLEOPTERA: ELATERIDAE)

By Arturs Neboiss, M.Sc., F.R.E.S.*

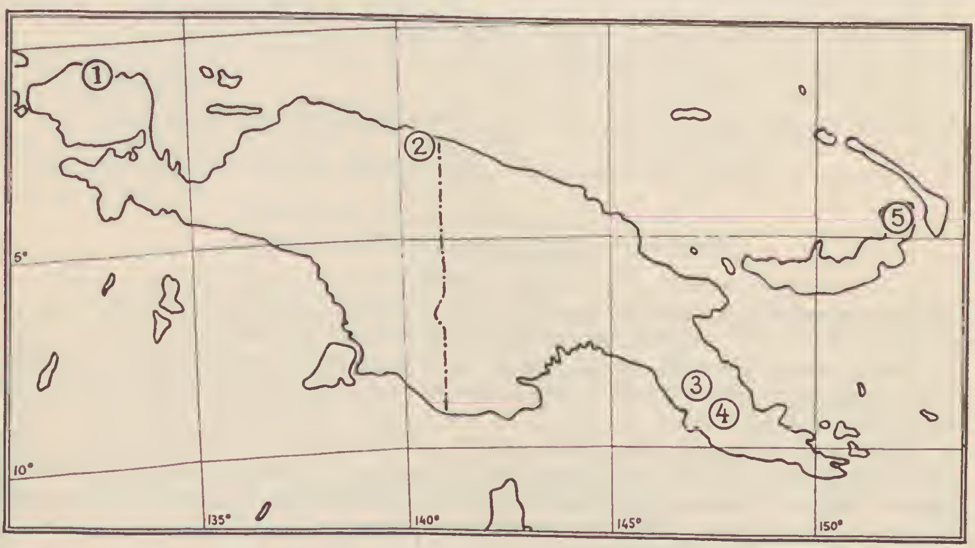
[Read 12 December 1957]

Abstract

The genus *Hapatesus* Candèze is now known from the Austro-Malayan Sub-region with five species, of which four are described in this paper as new. All these species belong to the subgenus *Hapatesus* sensu stricto, the subgenus *Minutesus* not being represented so far in this Sub-region.

Introduction

With the Australian *Hapatesus* material that was recently revised, a small collection of specimens from New Guinea and New Britain was received for study. Until the present time only one species was known from regions outside Australia, namely *Hapatesus hirtellus* Candèze, which was described from Dutch New Guinea in 1882. Apart from the original description only a few short references have been given to this species, and it was interesting to find that from twenty-six specimens now available for study only two belonged to the known species, the others belonging to distinct species that are described hereunder as new.



Locality map.

1—Amberbaki, Dutch New Guinea; type locality of *H. hirtellus* Cand. 2—Cyclops Mts., near Hollandia, Dutch New Guinea. 3—Mt. Tafa (8,500-9,000 ft.), Papua, Lat. 8° 38′ S.; Long. 147° 10′ E. 4—Kokoda, Papua. 5—Rabaul, New Britain.

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The genus *Hapatesus* Candèze (1863) is widely distributed in eastern Australia, and forms two distinct subgenera—*Hapatesus* s.str. and *Minutesus* (Neboiss, 1957). All species described in this paper belong to the former subgenus which is characterized in the male by having an apical hook on the lateral lobe of aedeagus, and in the female by the bursa copulatrix being without spiculation near the opening of spermathecal duct. Although generally very similar, New Guinea and New Britain *Hapatesus* species are separated from the Australian forms by having the pronotum more glossy because of the finer and sparser punctuation.

The available material is rather limited, and therefore the actual distribution of species is incompletely known, but some appear to have a wide range, e.g. *H. tropicus* is known from Rabaul, New Britain; Kokoda, Papua; and Cyclops Mountains, Dutch New Guinea; thus extending over a distance of more than 1,000 miles.

There is a small male specimen in the British Museum (Natural History) collection, labelled "Papua, Kokoda, 1,200 ft. Aug. 1933. L. E. Cheesman", and which differs from all other species discussed in this paper by its smaller size and other minute characters, but as no females are associated with this specimen, it has not been described hereunder.

Material for this study has been received from the British Museum (Natural History), London (BM); Hawaiian Sugar Planters' Association, Honolulu, Hawaii (HSPA); and the Institut Royal des Sciences Naturelles de Belgique, Brussels (IRSNB).

Key to the species of Austro-Malayan *Hapatesus*

1. Pronotum more or less evenly convex 2
   Pronotum flattened, median portion rising no higher than the carina .. *H. depressus* sp. nov.
2. Pronotum and elytra concolorous 3
   Pronotum orange brown, elytra darker reddish brown 4
3. Smaller species (7-8 mm.), yellowish brown .. .. *H. hirtellus* Cand.
   Larger species (9-10 mm.), dark reddish brown .. .. *H. obscurus* sp. nov.
4. Slender species; lamina dentata with spines extending beyond both lateral edges .. .. *H. linus* sp. nov.
   Species more robust, lamina dentata with spines extending beyond one lateral edge only .. .. *H. tropicus* sp. nov.

Hapatesus (Hapatesus) hirtellus Candèze

(Figs. 1 and 2)

Hapatesus hirtellus Candèze, 1882, *Mem. Soc. Roy. Sci. Liége*, (2) 9: 98.
Hapatesus hirtellus van Zwaluwenburg, 1948, *Proc. Hawaii ent. Soc.*, 13: 276.

Concolorous yellowish brown species, pronotum with darker anterior margin. Semi-erect, pale yellowish hairs scattered on dorsal surface, decumbent and finer on the ventral surface.

Head with triangular depression in the middle, anterior margin darker; eyes yellowish brown. Pronotum slightly longer than wide; sides rounded towards the anterior angles, posterior angles short; carina strong, close and parallel to the side margin; surface evenly convex, sparsely and finely punctate, interspaces glossy. Elytra 2·5 times as long as wide, sides subparallel to middle then gradually narrowed towards the apex; striae slightly impressed, finely punctate; intervals almost flat, glossy, with a row of fine punctures.

Lamina dentata very characteristic, triangular; spines relatively long, directed towards the apex, and not extending beyond the lateral edges.

Aedeagus slightly robust; apical hooks small; median lobe with rounded apex, furca wide and short.

The specimens ascribed to this species by van Zwaluwenburg (1948) have not been available for study by the present author. It is not certain whether these specimens really belong to *hirtellus*, or to one of the new species (*tropicus* or *linus*) described in this paper, especially observing the note that "the prothorax more brightly reddish than the elytra and have a longitudinal median blackish marking on the pronotum" which is rather a typical character to the two new species. (See *H. tropicus.*)

Length 7-8 mm., width 2·5 mm.

Type material: Type ♀, Amberbaki, Dutch New Guinea (IRSNB). ♂ genitalia drawn from a specimen from Cyclops Mts. near Hollandia, Dutch New Guinea (HSPA).

Hapatesus (Hapaetsus) linus sp. nov.

(Fig. 3)

Head, antennae, elytra and legs reddish brown; pronotum orange brown with an indistinct darker longitudinal median marking, and darker anterior margin. Dorsal surface sparsely covered with fine semi-erect pale yellowish hairs, ventral surface with decumbent pubescence.

Central triangular depression on the head present, but not very distinct; eyes black. Pronotum slightly wider than long, sides parallel in the posterior two-fifths, then gradually narrowed towards the anterior angles; carina strong, more or less parallel to the side margin; surface sparsely and finely punctate, interspaces glossy. Elytra 2·6 times as long as wide, sides gradually narrowed towards the apex; striae moderately impressed, finely punctate; intervals flat, comparatively wide, shiny, each with a row of fine irregular punctures.

Lamina dentata relatively large, spines more or less uniform in size, some of them slightly larger, extending beyond the two lateral edges.

♂ unknown.

Length 9-10 mm., width 2·5-3 mm.

Type material: Holotype ♀ and paratype ♀: Cyclops Mts., Mt. Lina, Dutch New Guinea 3,500-4,500 ft. March 1936. L. E. Cheesman (BM).

Hapatesus (Hapatesus) tropicus sp. nov.

(Figs. 4 and 5)

General colour dark blackish brown; pronotum lighter orange-brown with a blackish central longitudinal marking. Dorsal surface covered with pale yellowish semi-erect hairs, ventral surface with decumbent pubescence.

Central triangular depression on the head distinct, punctures moderate; eyes dark brown. Pronotum wider than long, sides almost parallel as far as the anterior third, then rounded towards the anterior angles; surface finely punctate, interspaces glossy; carina strong, more or less parallel to the side margin. Elytra approximately 2·4 times as long as wide, sides subparallel to the middle, then gradually rounded towards the apex; striae moderately impressed, finely punctate; intervals only slightly raised, each with a row of irregular punctures.

Lamina dentata elongate, triangular, spines more or less uniform in size, but with a row of larger spines extending beyond the longest lateral edge.

Aedeagus very similar to that of *H. hirtellus*, but is more slender; median lobe pointed, but furca slightly longer.

Length 7·5-10 mm., width 2·5-3 mm.

Type material: Holotype ♀, allotype ♂ and 1 paratype ♀: Rabaul, New Britain, April 1937 (HSPA); 5 other paratypes BM collection: 1 ♀ Cyclops Mts., Sabron,

930 ft., May 1936; 1 ♀ Mt. Cyclops, 3,500 ft., March 1936; 1 ♂ Cyclops Mts., 3,400-4,500 ft., March 1936; 1 ♂, 1 ♀ Kokoda, Papua, 1,200 ft., August 1933, collected by L. E. Cheesman.

Through the courtesy and co-operation of Dr. J. F. Gates Clarke, and T. J. Spilman, both of the Smithsonian Institution, Washington, U.S.A., to whom I express my sincere thanks, I was able to examine part of the material collected by B. Malkin in 1945, and later identified by Van Zwaluwenburg as *Hapatesus hirtellus* Candèze, as well as some other specimens. The material consisted of six specimens (4 ♂ ♂ 2 ♀ ♀) from Hollandia, Dutch New Guinea, collected 1945 by B. Malkin; 1 ♀ from the same locality 27.7.1944, and 1 ♀ from Nazab, Markham River, New Guinea, 6.1944, both collected by K. V. Krombein. The examination showed that all these specimens belong to *Hapatesus tropicus* sp. nov.

This material became available during the publication of this paper.

Hapatesus (Hapatesus) obscurus sp. nov.

(Figs. 6 and 7)

Almost unicolorous dark reddish brown species, with the exception of legs and antennae which are somewhat lighter in colour; pronotum with indistinctly darker longitudinal median marking. Hairs on dorsal surface fine, semi-erect, almost white; those on the ventral surface decumbent.

Head with somewhat triangular depression, moderately punctate; eyes brown. Pronotum only slightly wider than long, evenly and strongly convex; sides gradually contracting towards the anterior angles; carina strong, parallel to the side margin; surface finely and sparsely punctate, interspaces glossy. Elytra 2·3 times as long as wide, sides subparallel to the middle, then gradually curving towards the apex; striae moderately impressed, punctate; intervals almost flat, each with a row of fine irregular punctures.

Lamina dentata elongate, triangular, a number of slightly larger spines extending beyond the longest lateral edge.

Aedeagus more slender than in *H. hirtellus*, apical hooks small, furca of the median lobe short and wide.

Length 9-10 mm., width 2·6-3 mm.

Type material: Holotype ♀: Papua, Kokoda, 1,300 ft., September 1933; allotype ♂: Papua, Kokoda, 1,200 ft., June 1933; paratypes 1 ♀ and 2 ♂ ♂ Papua, Kokoda, 1,200 ft., May, June and August 1933. All specimens collected by L. E. Chessman (BM).

Hapatesus (Hapatesus) depressus sp. nov.

(Figs. 8 and 9)

Generally dark reddish brown, with slightly lighter coloured pronotum. Hairs on dorsal surface moderately dense, almost decumbent, with a few semi-erect near the sides of elytra, pale yellowish; those on the ventral surface finer and decumbent.

Head flat, with triangular central depression; eyes very dark brown. Pronotum distinct, flattened, slightly wider than long; median portion rising no higher than the carina, slight longitudinal depression on either side parallel to the margin; surface moderately punctate, interspaces glossy. Carina with lateral concavity near the posterior third, where it is furthest from the side margin. Sides gradually contracting towards the anterior angles. Elytra 2·7 times as long as wide, subparallel to the middle then gradually contracting towards the apex. Striae moderately impressed, punctate; intervals slightly convex or flat, each with a row of irregular punctures.

FIGS. 1-9

Lamina dentata small in comparison with the size of the specimen, spines small, directed towards the apex, and extending beyond the longest lateral edge. Apices of the two chitinous rods as well as the apex of the chitinous extension of eighth sternite clavate.

Aedeagus moderately robust; median lobe straight, apex pointed.

Length 11-12·5 mm., width 3-3·5 mm.

Type material: Holotype ♀, allotype ♂: Papua, Mt. Tafa, 8,500 ft., March 1934. L. E. Cheesman (BM).

There are two other female specimens referred to this species. Both are collected at the same place and date as the types, but apices of the two chitinous rods and the chitinous extension of eighth sternite are not clavate, specimens are slightly smaller and lighter coloured. Because of these differences these two specimens are not selected as paratypes. More material is necessary to establish the correct relationship between the specimens.

Acknowledgements

I would like to express my sincere thanks to Miss Christine von Hayek of the British Museum (Natural History), London, Dr. J. M. Vrydagh of the Institut Royal des Sciences Naturelles de Belgique, Brussels, and Dr. F. A. Bianchi of the Hawaiian Sugar Planters' Association, Honolulu, for loan of this very interesting material on behalf of the respective institutions.

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Explanation of Figures

FIG. 1.—*H. hirtellus* Cand., lamina dentata.
FIG. 2.—*H. hirtellus* Cand., aedeagus.
FIG. 3.—*H. linus* sp. nov., lamina dentata.
FIG. 4.—*H. tropicus* sp. nov., lamina dentata.
FIG. 5.—*H. tropicus* sp. nov., aedeagus.
FIG. 6.—*H. obscurus* sp. nov., lamina dentata.
FIG. 7.—*H. obscurus* sp. nov., aedeagus.
FIG. 8.—*H. depressus* sp. nov., lamina dentata.
FIG. 9.—*H. depressus* sp. nov., aedeagus.

9

STRIPPED ZONES AT CLIFF EDGES ALONG A HIGH WAVE ENERGY COAST, PORT CAMPBELL, VICTORIA

By George Baker

[Read 12 December 1957]

Abstract

Stripped zones, which vary from a few feet to approximately sixty yards wide according to cliff height, have been produced, by storm action, at the edges of the tops of marine cliffs cut in soft Miocene limestone, and are marked features of the high wave energy karst coast of the Port Campbell district.

They are best developed in positions most exposed to frontal wave attack where relatively deep water occurs at cliff bases. Stripping away of materials forming a thin veneer to the Miocene limestone at cliff edges, is accomplished by storm waves, aided by surface run-off of rain-waters, and to a lesser extent, wind action.

The local geomorphology of the stripped zones is dominated by small-scale, but prominent, features such as protruding accretionary growth structures, basin-like depressions, small sink-holes, and, at the seaward edges of the stripped cliff-tops, solution-abrasion pipes.

Introduction

Stripped zones are relatively common at the edges of the tops of steep, high, marine cliffs cut in Tertiary (Miocene) aphanitic limestone in the Port Campbell district, south coast of western Victoria. They are best developed at the seaward edges of the cliff-tops in marine environments where attack by on-shore wave systems is most strong. High energy wave attack is here influenced by a long fetch of several thousand miles, and is largely controlled by southwesterlies as the major wind resultant. Surface run-off of rain-water in a region subject to relatively frequent coastal showers and occasional severe storms, assists and subsequently becomes an important factor in removing superficial materials from the edges of vertical cliffs.

The stripped zones are marked features of several short stretches of this high energy karst coastline, extending along the edges of the cliff-tops for distances of from tens of yards to over 400 yds. They are most pronounced at such exposed portions of the coastline as Point Hesse, Gravel Point, the Amphitheatre, Broken Head and environs, and the seaward ends of smaller promontories in the region of Loch Ard Gorge (see Baker, 1943, p. 362, Fig. 3). These are positions where relatively deep water occurs right up to the cliff bases, so that wave attack is unimpeded by cliff talus, or by shore platforms or by sandy and pebbly beaches; wave energy is thus at a maximum for such parts of the coastline. Storm waves are able to break high up directly on to cliff faces, well above the visor zone, and significant amounts of large masses and clumps of spray are frequently tossed up on to the edges of cliff-tops. Where protecting features occur at cliff bases, or in more sheltered positions where cliffs trend normal to the wave front and wave energy is moderated, or wherever cliff height is too great, stripped zones are absent from the cliff-tops.

Agents Producing the Stripped Zones

Stripped zones result where the action of tossed-up clumps of sea-spray and rain-waters combine to remove vegetation, soils, subsoils and Post-Miocene Clays from

the edges of the cliff-tops, thereby exposing the more or less horizontally bedded Port Campbell Limestone (Miocene), with its abundant content in places of calcareous accretionary growths. Along the edges of such cliff-tops, the effects of erosion are dominant over those of deposition; the matrix of the Port Campbell Limestone is more prone to rapid weathering, and the accretionary growth structures become exposed as prominent, if relatively small-scale projecting features in the local geomorphology (Pls. XXVII and XXVIII).

The width of the stripped zone landwards from cliff edges, is largely controlled by cliff height. The widest, which are some 60 to 70 yds. across and rarely wider, occur where cliff-tops are 10 ft. and up to 60 ft. above normal tide level, for here, the stripped zones are within the range of attack by average storm waves striking vertical to backward sloping steep cliffs at the right angle. At the edges of cliffs rising 60 to 200 ft. above normal tide level, stripped zones dwindle to a few feet in width, and are only occasionally attacked under the most severe gales (south-westerlies). Edges of cliffs above 200 ft. high, do not possess stripped zones; their seaward edges are marked by small bevels caused by partial soil-slip.

Nature of Exposed Surfaces

The surfaces of the stripped zones are seldom horizontal despite the horizontally-bedded nature of the limestone; they usually have a gentle seaward slope produced by subaerial erosion. Smooth undulations of the surface characterize the landward regions of examples up to 50 or 60 ft. above sea level, while towards their seaward edges, where accretions and accretionary growth layers are better exposed (Pl. XXVII, fig. A), the surface is invariably ragged and craggy. Such surfaces are principally swept free of all loose materials except for the very coarsest of rock rubble, which sometimes remains strewn over parts of the stripped zones, or is more often concentrated along the rather more steeply sloping landward fringe, just below the zone of soil and vegetation. Broader stripped zones situated nearer sea level (i.e. some 10 to 20 ft. high), usually have much pitted surfaces, especially near their seaward edges. The pitting sometimes assumes a relatively regular cellular pattern, and parts of the surface have been eroded along prominent joint planes, other parts carry a number of rock pools of varying depth and diameter, while the only rock debris present consists of large boulders on the surface of the stripped zone, smaller grinder pebbles and cobbles in the rock pools. Landward from the pitted regions, the surfaces become much smoother.

Processes Operating on Exposed Surfaces

After removal of the veneer of vegetation, soil, subsoil and Post-Miocene Clay by mechanical processes in the initial phases, the exposed portions of the Port Campbell Limestone constituting the surface of the stripped zones, become subjected to weathering in various ways. The factors operating to produce and maintain the stripped zones at the edges of cliff-tops in favourable positions for development, include—

(a) chemical solution by rain-water;

(b) fritting by wind-driven media, including rain, sea-spray and occasionally small rock and mineral particles (e.g. quartz grains, small fragments of accretions, etc.);

(c) hydrostatic pressure of large breaking storm waves that reach heights of over 100 ft. on parts of the cliffs during severe tempests;

(d) abrasive action of water-borne sand, "buckshot gravel", and the harder portions of broken-off limestone (more especially pieces of the calcareous accretions). These are carried by (i) surface run-off waters flowing over exposed parts of the Post-Miocene Clay veneer which occurs at the landward fringe of practically all the stripped zones, below the zone of vegetation and soil, and (ii) by the surf thrown up from large breaking storm waves, which often pick up and move about any already dislodged accretions present.

The chemical factors involve a process of leaching, brought about by surface run-off waters composed largely of rain-water relatively low in salt concentration (from cyclic salts), but containing certain carbon dioxide compounds and hence possessing a pH value less than that of sea-water. This is capable of dissolving materials that would not pass into solution so readily if they were in constant contact with sea-water, the pH of which is approximately 7·5 to 8·4 (Sverdrup, Johnson and Fleming, 1942, p. 213). Under these conditions, the softer aphanitic limestone host tends to disintegrate more rapidly than the contained accretionary growths.

Mechanical factors involve traction of larger fragments of rock rubble during storms, when the impact of large breaking waves directed fully or obliquely against vertical to slightly backward-sloping, high cliff faces, causes large clumps and masses of sea-water and sea-spray to be thrown high up on to the edges of the cliff-tops; on receding, these, where sufficiently strong in their run-back, drag rock rubble over the limestone surface towards the cliff edges. At the same time, the effects of hydrostatic pressure of the large breaking waves, even at the greater heights, result in fracturing and ultimate dislodgement of some of the projecting accretions, and also the opening up of joint and bedding planes in the limestone.

The effects of alternate wetting by salt spray and drying out of the softer, more porous limestone matrix in places, assist in the disintegration of the limestone. This is partly evidenced by the occasional disruption of certain included fossils on crystallization of NaCl. The denser accretions are not so much affected by this process, although often observed to be encrusted with thin films of salt when dry. Subsidiary mechanical effects involve fritting by wind-driven media and abrasion by the smaller products of erosion transported across the stripped zones by surface run-off after rain.

Since the processes operating on the stripped zones are dominantly directed towards erosion, rather than precipitation, it is evident that the calcareous accretions in the Port Campbell Limestone are not being developed at the present time, in fact, under the prevailing conditions, the greater tendency is towards their destruction; all the evidence points rather to the accretions being syngenetic in origin.

Consequent Rock Sculpture

A feature of several of the stripped zones is the presence of shallow, basin-like depressions formed in the soft limestone (Pl. XXVIII, figs. G and H) between aggregates of accretionary growths. They result partly from solution, partly from local over-deepening by surface run-off waters, the sites of development being largely determined by the positions and degrees of exposure of the accretionary growth structures, which in large measure cause directed scour of the leached limestone. These depressions are often partially infilled with finer rock rubble, "buckshot gravel", sand and clay, which, when dry, sometimes reveal "mud-curls" on the surface (Pl. XXVIII, fig. H). A few of the depressions ultimately develop into small sink-holes. Others have been transected by landward cliff-edge recession, and their

uncompacted infillings largely removed, thus revealing solution-abrasion pipes up to 20 and 30 ft. deep and 10 to 20 ft. in diameter.

Other features of the stripped zones are the variable pattern of accretions (Pl. XXVII, figs. A and B; Pl. XXVIII, fig. F), which help to determine the development of more resistant shelves (Pl. XXVII, fig. B) and small "outliers" composed of a protective capping of accretionary growth layers, set on pedestals of softer limestone more or less free of accretions (Pl. XXVII, fig. D). Some accretionary growths weather to bowl-like structures with honeycombed walls (Pl. XXVIII, fig. E); more rarely they appear as small ring-like structures (Pl. XXVIII, fig. F). Water overflowing from the perched bowl-like structures, occasionally develops small basin-like depressions in the softer host Port Campbell Limestone (Pl. XXVIII, fig. E) one to two ft. below the level of the edge of the bowl.

Where sufficiently concentrated in the limestone of the stripped zones, the accretionary growths dominate the minor features of local rock sculpture. Where situated lower down in the steep cliff faces, and hence more frequently attacked by the waves, concentrations of accretions arranged along horizontal planes, help to control the positions and size of notches (including visors), ledges and lower platforms. The wave-cut notches are in softer limestone or in calcareous clay situated sometimes above, sometimes below, occasionally between layers of accretions, while the ledges and platforms are frequently surfaced by accretionary growth layers. Weathered-out accretions lying on ledges, platforms and stripped zones, more particularly on the latter, often show grotesque and irregular shapes.

On one or two of the stripped zones located at approximately 100 ft. above sea level, occasional mounds up to 6 ft. high, consist of loose, irregularly-shaped blocks a foot or so across of limonitic accretionary growths; these are pronounced features at Gravel Point, 3 miles east of Port Campbell township. Originally formed as ferruginous accretions beneath the surface soils but above the Post-Miocene Clay veneer, they remain on top of the stripped zones longer, because of their larger size, their greater density and their more durable character compared with neighbouring and enclosing materials (lateritic soils and Post-Miocene Clay) which are fairly readily removed once the vegetation cover has been destroyed.

Owing to the combined effects of storm-tossed spray and limited stream channel flow of surface drainage along one or two parts of the Port Campbell Limestone Coastline, stripped zones are occasionally amphitheatre-like. The best-developed of this special type occurs at The Amphitheatre at the mouth of Ingle's Creek, $3\frac{1}{4}$ miles east of Port Campbell township, where the stripped zone is arcuate in plan, stepped in cross-sectional aspect, and is located some 50 ft. above normal sea level. It has thus been produced at the mouth of a small hanging valley, where marine erosion strongly dominates stream erosion. On the headlands, however, and elsewhere where hanging valleys are absent, the stripped zones normally trend parallel with relatively straight stretches of the cliff edges.

Stripped zones comparable in general characteristics and positions of development, also occur from place to place along the cliffed coastline constituted of similar sediments (Port Campbell Limestone), extending westwards from Peterborough to beyond Childers Cove on the southern coast of western Victoria.

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Description of Plates

Plate XXVII

Features of stripped zone some 30 to 40 yds. wide at seaward edge of cliff-top 60 ft. above sea level. East side of Broken Head, 4 miles south-south-east of Port Campbell, Victoria.

Fig. A.—General view showing calcareous accretions exposed as ragged projections from the softer Port Campbell Limestone matrix, and forming a craggy surface.

Fig. B.—Calcareous accretions forming more resistant shelf-like structures standing up to 3 ft. above the softer limestone. On further weathering, these shelves of layer-like accretions are stepped in parts and sometimes slightly overhanging.

Fig. C.—Numerous small, nodular calcareous accretions scattered through softer limestone matrix below the layer-like accretionary growths (match-box = 2 in. long).

Fig. D.—Small "outlier" of layered, bedding plane accretionary growths of calcium carbonate, capping a partially undercut pedestal of softer limestone. Undercutting of pedestal more marked on seaward side, while profile of pedestal slopes more gently in the erosion shadow on the landward (lee) side. Small, partially infilled basin at foot of pedestal on lee side.

Plate XXVIII

Features of stripped zone some 30 to 40 yds. wide at seaward edge of cliff-top 60 ft. above sea level. East side of Broken Head, 4 miles south-south-east of Port Campbell, Victoria.

Fig. E.—Bowl-like accretionary growth perched on pedestal, 2 ft. above general level of stripped zone. Rock rubble occurs in bowl-like structure, and small basin in softer limestone at foot of pedestal on down-drainage side (match-box = 2 in. long).

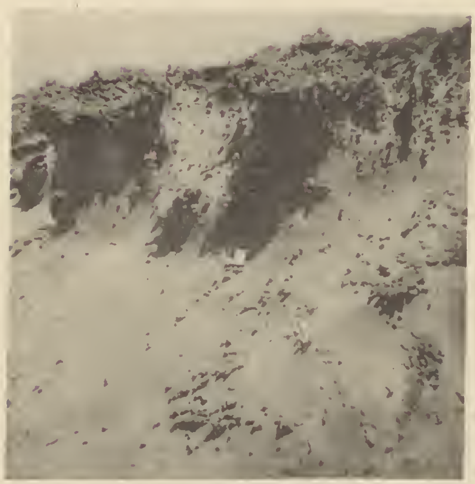
Fig. F.—Plan aspect of jagged and ring-shaped calcareous accretionary growths exposed some 2 to 3 in. above the level of the general surface of the stripped zone. Minor ridges in softer limestone at bottom right of photograph, represent the tops of emergent accretionary growth structures.

Fig. G.—Small basins 3 to 4 ft. across, developed in the softer limestone some 2 to 3 ft. below the level of calcareous accretions exposed on the surface of the stripped zone. Basins are partially infilled with rock rubble (mainly broken fragments of calcareous accretions, and "buckshot gravel") covered by fine sand and clay.

Fig. H.—"Mud-curls" resulting from desiccation and breaking up of superficial clay veneer into polygons, on top of partially infilled basin approximately 6 ft. long.

A

B



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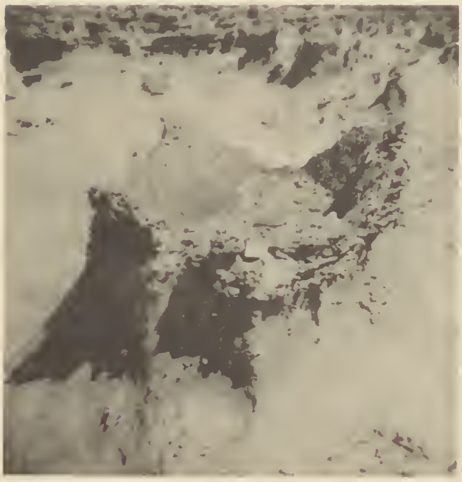
D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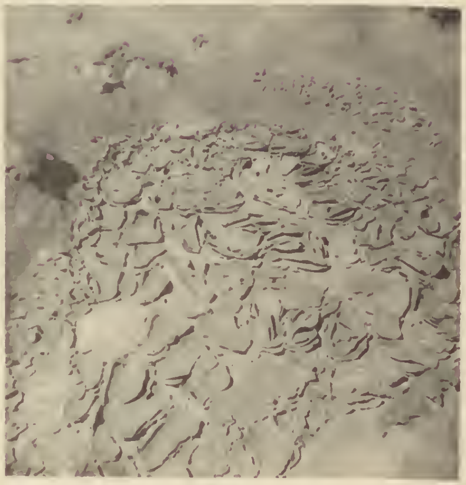
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10

THE JURASSIC SEDIMENTS OF THE TYERS GROUP, GIPPSLAND, VICTORIA

By G. M. Philip

[Read 12 December 1957]

Abstract

The Jurassic rocks of the Tyers Group comprise 2,000 ft. of sediments marginal to the main Jurassic basin in Gippsland. They are conglomerates, greywackes, sandstones (protoquartzites) and typical Jurassic felspathic sandstones with mudstones and minor coal seams present throughout the sequence. The normal felspathic sandstones of the Jurassic are regarded as arkoses rather than subgreywackes as has recently been suggested by Pettijohn (1957). Primary current features—cross-bedding measurements and pebble orientation studies within the conglomerates—together with matching rock types from the Tyers Conglomerate, indicate that the source of the basal part of the Tyers Group was the Siluro-Devonian greywackes to the north. The normal felspathic sandstones at the top of the sequence represent detritus brought in by current action derived from the same general source as the rest of the Jurassic. The conglomerates and the greywackes indicate rapid sedimentation whereas the sandstones (protoquartzites), which are "washed" greywackes, are the products of more stable sedimentation, an approach to that under which the felspathic sandstones of the Jurassic were deposited.

Introduction

The Jurassic sediments of Victoria are a widespread and uniform series. They are lacustrine sediments consisting characteristically of cross-bedded felspathic sandstones (arkoses) interbedded with mudstones. Grits and bituminous coal seams occur throughout the sequence to a much lesser degree while coarse conglomerates occur around the margins of the basin. The Jurassic sediments described in this paper contain the greatest known development of such conglomerates, although minor conglomerates mark the base of the sequence elsewhere (Edwards and Baker, 1943). Moreover, they contain sandstones distinctly different from the normal Jurassic "arkoses". They outcrop north of the Latrobe River in the Parishes of Tanjil East and Boola Boola and are here named the Tyers Group.

Murray (1876, 1887) first recorded the occurrence of Jurassic rocks in this part of Gippsland, and his original description is still the most complete. Whitelaw (1899), Easton (1908), Skeats (1935), Edwards and Baker (1943) and also Medwell (1954) have briefly mentioned the massive conglomerates which occur at the base of the sequence. Easton (1908) roughly mapped the boundaries of the Jurassic in this area, while Whitelaw (1926) published a coloured parish plan showing the geological boundaries in more detail within the Parish of Tanjil East.

The Tyers Group is well exposed along the valleys of Anderson's Creek, Tyers River, and Rintoul's Creek. It has a strike length of more than 14 miles with a regional dip of about 12° to the SSE. increasing to 20° in the east. To the north the Jurassic sediments unconformably overlie strongly-folded Siluro-Devonian greywackes, shales, conglomerates and limestones of the Walhalla "Series" and unnamed mudstone equivalents of the Tanjilian. The Tyers Group itself is unconformably overlain by Tertiary rocks. These consist of clays, then brown coals (exposed in Stony Creek) and quartzites overlain by Tertiary Older Volcanic basalt and the Latrobe Valley Coal Measures, which are in turn overlain by widespread sands and

gravels, probably equivalents of the Haunted Hill Gravels of Thomas and Baragwanath (1949). The land surface on which these gravels were deposited appears to be sloping southward almost parallel to the present dissected land surface. Because of the extensive cover of Tertiary rocks good exposures are to be found only along river valleys.

To the west the Tyers Group is truncated by a fault. This is well exposed in road cuttings in the valley of a small east-flowing tributary of Anderson's Creek. Here the topmost beds of the Tyers Conglomerate dipping at 12° to the east can be seen directly abutting against almost vertical Siluro-Devonian mudstone. Thomas and Baragwanath (1949) have mapped a N.-S. trending fault about half a mile further westward called the Haunted Hill Fault. This fault is downthrown to the west in order to explain the difference in height between the brown coals and Palaeozoic sediments along the Latrobe River. In order to avoid possible confusion with this fault, the fault along the boundary of the Jurassic is here named the Anderson's Creek Fault. It is downthrown to the east with a displacement of over 1,000 ft. Where it is exposed near Anderson's Creek it trends almost N.-S. It is apparently a northward continuation of the Yallourn Monocline after it swings eastward. The Haunted Hill Gravels do not appear to be affected by it.

To the south the Tyers Group is truncated by the Yallourn Monocline, a structure which can be seen at the bridge across the Latrobe River at Yallourn and was well exposed in the excavations for the power station at Yallourn. Field indication of the monocline is best seen along the Tyers River where there is an increase in southerly dip of the Jurassic from 8° to 40° over a distance of less than half a mile. The complementary turn-up of the Latrobe Valley Coal Measures along the monocline can be seen at Yallourn North Open Cut. To the east the Jurassic again appears to be truncated by a continuation of the Yallourn Monocline, here trending NE. parallel to the present margins of the Latrobe valley. Lignitic clays and sandstones, apparently part of the Latrobe Valley Coal Measures, can be seen dipping eastward at 30° in the valley of Eaglehawk Creek where it leaves the foothills and flows out on to the flood plain of the Latrobe River. These sediments appear to lie within the monocline. Rocks similarly disposed were found still further north in the valley of the Thompson River in exploratory excavations down-stream from the Cowwarr diversion weir (Mr. Harding, personal communication).

South of the monocline, Jurassic rocks apparently underlie much of the Tertiary basin containing the Latrobe Valley Coal Measures. South of the Latrobe valley, Jurassic rocks again outcrop and comprise most of the South Gippsland highlands. (The Strzelecki Group of Medwell, 1954.)

Four measured sections were made through the Tyers Group along Stony Creek, Rintoul's Creek, the Tyers River and Anderson's Creek. These, together with a section compiled from field data collected at Yallourn North by Mr. F. Beavis of the Department of Geology, University of Melbourne, are summarized in Fig. 2.

Acknowledgements

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Classification of the Jurassic Sandstones

(A) Description

The normal basin sandstones of the Jurassic sequence of Victoria constitute a remarkably uniform rock type. The petrology of these sediments has been studied in detail by Edwards and Baker (1943). Briefly, the sandstones are characteristically medium-grained, and when fresh are greenish-grey, due to the presence of abundant chlorite cement. Where the rock is weathered the chlorite is oxidized to limonite and the rock is brown. In thin section the sandstones are seen to consist essentially of rounded to sub-angular igneous rock fragments, comparatively fresh felspars which are chiefly oligoclase with lesser amounts of orthoclase and angular quartz grains set in a chloritic cement (Pl. XXIX, fig. 1). Locally the cement is calcareous. There is little or no matrix. Micrometric analyses of several typical sandstones is given in Table 1.

Table 1

Micrometric Analyses of Typical Felspathic Sandstones of the Jurassic of Victoria

Constituents	1	2	3	4	5*
Rock fragments	43·6	41·8	44·9	37·3	44
Felspar	28·1	23·0	23·6	24·5	27
Quartz	10·1	14·6	13·0	9·8	10
Matrix	—	3·8	3·0	3·5	3
Cement†	17·7	16·0	15·3	20·6	15
Minor detrital minerals ..	0·5	0·8	0·2	4·3‡	1

* Approximate only as sandstone was weathered.
† Chlorite, zeolitic material and occasional partly-filled voids.
‡ Including 3·6 per cent carbonaceous material.

1. Griffith's Point, San Remo Peninsula.
2. Apollo Bay.
3. Lorne.
4. Tarra Valley, Gippsland.
5. Tcp of section, Anderson's Creek, North Yallourn.

The notable feature shown in this table is the high percentage of igneous rock fragments present in the sandstones, in places over 50 per cent of the detrital fraction of the rock. They all appear to be fragments of fine-grained to glassy andesite or andesite tuff.

Of particular interest also is the chloritic cement. This was regarded as a matrix by Richards (1909), but its true nature as an introduced chemical cement cannot be in doubt. It can be well seen in Plate XXIX, fig. 1, where it fills the spaces between the grains. In this particular sandstone from Griffith's Point, San Remo, the grains have been first overgrown or cemented by a thin film of what is either authigenic albite or a zeolitic mineral. Some of the spaces between the grains have been only partially filled by chlorite and voids have been left. In these interstices the chlorite is acicular with the long axes of the crystals of chlorite normal to the surface they encrust.

The origin of the chlorite is speculative. Edwards and Baker (1943) showed the mudstones associated with the sandstones to be rich in chloritic material, and concluded that the cement was introduced into the sandstones by connate waters asso-

ciated with the mudstones. Chlorite cement in sandstones is uncommon. James (1954) has considered the large amounts of chlorite present in the iron formations of the Iron River and Crystal Falls districts of Michigan to be produced by the interaction of iron-rich sea-water and the finer fraction of the clastic material. However the chlorite cement of the Jurassic sandstones cannot be regarded as the reconstitution during diagenesis of a pre-existing matrix as some evidence of this would be seen in thin section. The widespread and uniform character of the cement does suggest that the source of the cement was within the Jurassic. Also, as the porosity of the rock is severely reduced by the presence of the cement, many local sources must be postulated rather than one main source.

(B) Classification

On the basis of Twenhofel's (1932, p. 229) definition of an arkose as a "sedimentary rock composed of material derived from the disintegration of acid igneous rocks of granular texture", Edwards and Baker classified the Jurassic sandstones as arkoses.

Most authors have followed closely the original definition of an arkose given by Brongniart (1826) as a sedimentary rock "composed essentially of large grains of glassy quartz and grains of lamellar, compact or clayey felspar: these two minerals are often mixed in more or less equal quantities but more often the quartz is dominant." (Oriel, 1949, p. 826.) No real agreement has been reached as to the composition of an arkose, but most authors are of the opinion that felspar should constitute more than 25 per cent of the rock (e.g. Allen 1936, Pettijohn 1949, Tallman 1949, Dapples, Krumbein and Sloss 1953, Krumbein and Sloss 1953, Carozzi 1953). Krynine (1940) set the lower limit of the felspar as being 30 per cent but later (1948) showed the average felspar content of his arkose series to be 25 per cent. Further, most authors have stressed the low percentage of detrital matrix and the presence of a chemical cement. As can be seen in Table 1 the Jurassic sandstones of Victoria have in general more than 25 per cent felspar in the detrital fraction of the rock (i.e. with the chlorite cement omitted). Thus they can be regarded as arkoses as defined above.

Recently Pettijohn (1954, 1957) has proposed a classification of sandstones which is among the first to provide an adequate conceptual framework for the naming of arenaceous sediments. Pettijohn has used provenance and maturity indices which are much more reliable than those of other authors in that the labile and stable constituents are not mixed in the derivation of those indices. According to Pettijohn (1954, 1957) an arkose is a sandstone with little or no detrital matrix, with or without a chemical cement and containing over 25 per cent labile constituents (i.e. rock fragments and felspar) of which the felspars are more abundant. From Table 1 it can be seen that within this definition the normal felspathic sandstones of the Jurassic cannot be regarded as arkoses as the rock fragments are present in greater quantities than the felspar. Moreover, Pettijohn (1957, p. 323) has suggested that the Jurassic sandstones as described by Edwards and Baker are greywackes or subgreywackes. The first possibility can be quickly discounted because of the almost complete lack of detrital matrix. It seems then that within Pettijohn's (1954, 1957) classification, the Jurassic sandstones should be regarded as subgreywackes, i.e. sandstones with little or no detrital matrix, with or without a chemical cement and containing over 25 per cent labile constituents of which the rock fragments are the more abundant.

This later definition conflicts with the original definition of a subgreywacke given by Pettijohn (1949). Here the subgreywacke as defined was virtually synonymous with Krynine's "low-rank greywacke" and Fischer's "quartzwacke" or "quartz-

meng-wacke", sandstones which are products of a geosynclinal environment. In his later definition Pettijohn has attempted to define as a subgreywacke paralic "cyclothem" sandstones typified by the molasse of the Alps. This change in definition is confusing and not strictly permissible. The only way in which a universally accepted sedimentary rock classification can be maintained is by adhering rigidly to original definitions as Pettijohn (1943) has done for greywackes. Further confusion is likely to arise in that the term "subgreywacke" suggests a rock within the greywacke family, not a rock in origin related to arkoses. Clearly this leads to the possible confusion of greywackes with arkoses of which Krynine has stated, "the common mistake in the field of confusing arkoses . . . with greywackes . . . is sure to lead both to petrologic and interpretative disaster". (Krynine, quoted by Pettijohn, 1949, p. 260). For these reasons the author is of the opinion that the term "subgreywacke" should only be used as it was originally defined, synonymous with Krynine's "low-rank greywacke", the typical sandstones of a miogeosynclinal environment.

Because of the apparent inadequacy of the present compositional definitions of sandstones it is perhaps best to compare the examples which Pettijohn gives in illustration of his subgreywacke with the felspathic sandstones of Victoria to see whether they are truly analogous. Typically the subgreywacke of Pettijohn contains very little felspar. The Bradford Sand contains from traces to 1½ per cent and felspar nowhere exceeds 6 per cent of the rock (Krynine, 1940). The Oswego Sandstone contains from 3 to 5 per cent felspar (Krynine and Tuttle, 1941). The molasse itself usually contains very little felspar (Stiefel, 1957) but it may be present in appreciable quantities in places (Bersier, 1938). Rock fragments present may be up to 30 per cent of the rock, and are usually made up of sedimentaries or low-grade metamorphics, indicating that such a terrain constituted their source. Another feature is the high concentration of detrital chert in the rock which may be up to 30 per cent of the rock. This again indicates their derivation from a sedimentary terrain.

In contrast to this the Jurassic sandstones contain a considerable quantity of detrital felspar, enough for them to be regarded as arkoses by earlier definitions. The rock fragments are derived from a volcanic terrain and so are markedly different in character from those rock fragments of a subgreywacke. The difference in source rocks is also reflected in the virtual absence of detrital chert. Further it should be noted that the subgreywackes of Pettijohn (1954, 1957) are sandstones of a paralic environment, whereas the Jurassic has been deposited in a limnic environment (Edwards, Baker and Knight, 1944) which is more typical of arkoses.

An important morphological classification of sedimentary bodies was introduced by Krynine (1948). This classification is useful in distinguishing the various sedimentary associations as the shape of a sedimentary basin can be further correlated with its tectonic setting. For example, in general the orthoquartzite-carbonate association occurs mainly as "blanket" deposits in which the ratio of width to thickness of the deposit is over 1,000 to 1. The greywacke or "flysch" association occurs as tabular bodies in which the ratio of width to thickness is 50-1,000 to 1. Arkoses generally form prisms in which the width of the deposit is 5 to 50 times the thickness. The last category are the shoe-string bodies in which the width is under 5 times the thickness. Pettijohn (1957) states that the molasse or subgreywacke association (in his later sense) occurs typically as shoe-string sands.

This approach cannot be applied too rigorously to the Jurassic of Victoria as the margins of the basin are not accurately known. It is almost impossible to say whether there was a single large basin which has been broken up by later earth movements or a series of smaller basins. Because of the distinctive character of the andesite tuff fragments throughout the sandstones, Edwards and Baker (1943) have suggested a

single large basin of deposition. On the basis of this they have suggested that the "basin appears to be a narrow trough, not less than 350 miles, and probably more than 450 miles, long, and in width somewhat in excess of 50 miles" (p. 224). In Gippsland the margins of the basin can be fairly well established. To the south at Chitt Creek, near Toora, Ferguson (1906) has recorded a thin conglomerate bed apparently at the base of the Jurassic, while the Tyers Group to the north undoubtedly represents a marginal facies of the basin. This suggests that here the width of the basin was of the order of 40 miles.

The thickness of the Jurassic is not known. Selwyn (1868) estimated the thickness as 5,000 ft. (quoted by Edwards and Baker, 1943), the same as the estimate made by Hunter and Ower (1914) on the basis of incomplete bore data.

This suggests that using Krynine's classification, the Jurassic approximates to being "prism shaped" or perhaps even "tabular". Most certainly they are not "shoestring", the typical manner in which subgreywackes occur.

A question which remains is whether or not, because of the high percentage of volcanic rock fragments, the sandstones should be regarded as tuffaceous sandstones. The rounded and weathered appearance of many of the fine-grained to glassy rock fragments suggests, however, that they were derived by the normal processes of erosion from a volcanic terrain rather than being directly consolidated primary volcanic ejecta. The rock thus cannot be said to conform to the definition of a tuffaceous sandstone as given by Wentworth and Williams (1932). Bailey (1926) on the other hand defined a tuffaceous sandstone as a sedimentary rock composed either wholly or in part of volcanic material which has been transported and redeposited by water, using the term in a sense similar to the "transport-tuffe" of Walther and Schirlitz (1886). The term "tuffaceous sandstone" should be confined to sandstones in which the primary eruptive origin of the volcanic material can be established. More recently Hay (1952) has suggested that sandstones rich in detritus derived from older volcanic rocks should be called "volcanic sandstones", although he still persists with the term "tuffaceous sandstones" for those in which the volcanic fragments are less than 50 per cent of the total detrital content of the rock. Adjectives such as "volcanic" and "metamorphic" are possibly of restricted use as source designations in the major sandstone grouping, but difficulty arises in their application (Pettijohn, 1954).

It is concluded that the felspathic sandstones of the Jurassic of Victoria conform more closely to arkoses than subgreywackes in that they contain over 25 per cent detrital felspar and little or no chert, they are the products of a limnic rather than paralic environment, and they form an approximately prism-shaped body. On the other hand they cannot be regarded as true arkoses as defined by Brongniart (1826) because of the very low percentage of quartz and the high percentage of rock fragments.

A very different approach from Pettijohn's is that of Folk (1954). In the classification of sandstones he would include all igneous rock fragments with felspar. On this basis the Jurassic sandstones may clearly be regarded as arkoses. For arkoses containing significant amounts of fragments of igneous rocks Folk has suggested the term "volcanic-bearing". The felspathic sandstones of Victoria are arenites of this type.

Sediments of the Tyers Group

(A) Tyers Conglomerate

This name has been applied to the conglomerates at the base of the series by Medwell (1954). Where they outcrop along the Tyers River they are a striking lithologic unit forming cliffs which rise over 400 ft. above the river level.

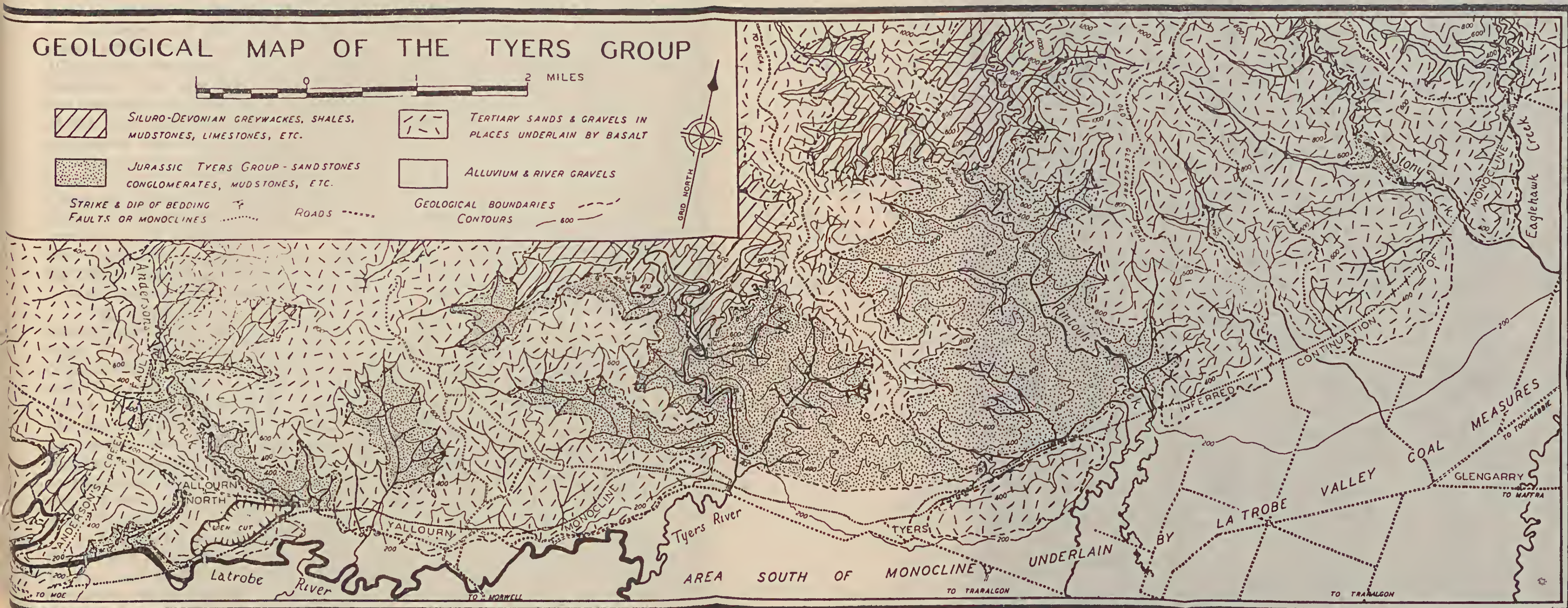
GEOLOGICAL MAP OF THE TYERS GROUP
0 1 2 MILES
SILURO-DEVONIAN GREYWACKES, SHALES, MUDSTONES, LIMESTONES, ETC.
TERTIARY SANDS & GRAVELS IN PLACES UNDERLAIN BY BASALT
JURASSIC TYERS GROUP - SANDSTONES CONGLOMERATES, MUDSTONES, ETC.
ALLUVIUM & RIVER GRAVELS
STRIKE & DIP OF BEDDING
FAULTS OR MONOCLINES
ROADS
GEOLOGICAL BOUNDARIES
CONTOURS
GRID NORTH
YALLOURN NORTH
YALLOURN
MONOCLINE
Latrobe River
Tyers River
TYERS
AREA SOUTH OF MONOCLINE UNDERLAIN BY LA TROBE VALLEY COAL MEASURES
INFERRED CONTINUATION
GLENGARRY
Stony Ck.
Eaglehawk Creek
TO MOE
TO MORWELL
TO TRARALGON
TO MAFFRA

FIG. 1.

They consist of massive conglomerates with well-rounded cobbles of low sphericity. Occasional boulders, whose longest dimension is over one foot, occur throughout the exposures. Towards the top of the unit the cobbles become significantly smaller and many enter the pebble class (of the Wentworth-Udden size terms, i.e. between 64 and 4 mm.). Cross-bedded sandy intercalations are present within the conglomerate but here they are rarer than anywhere else. In places cement and matrix are virtually absent (Pl. XXX, fig. 3), and only a little unlithified sand occurs between the pebbles and cobbles. More usually and especially towards the top of the conglomerate it "is cemented with ferruginous and siliceous material" (Murray, 1876, p. 141). In general the conglomerate is buff in colour.

In composition the conglomerate is typically polymictic. An average of three rough pebble counts gives the composition as 73 per cent fine-grained greywacke, 10 per cent vein quartz, 6 per cent gritty greywacke, 4 per cent quartzite, 4 per cent mudstone, 3 per cent shale. Locally these percentages vary considerably. Vein quartz, the fragments of which tend to be subangular, often makes up an important fraction of the finer material in the conglomerate. These rock types, except for the gritty greywacke, can be matched perfectly with the rock types occurring in the Siluro-Devonian to the north. Low down in the sequence a fossiliferous pebble of the "Basal Conglomerate" of the Walhalla Series was recognized. To the west in Anderson's Creek the Siluro-Devonian sandstones immediately to the north and underlying the Tyers Conglomerate consist of pale-buff-coloured greywackes with a distinct concentration of detrital tourmaline. In this area cobbles of this rock form a significant part of the Tyers Conglomerate. North of the Jurassic contact along Stony Creek the Siluro-Devonian consists of an extensive series of soft highly contorted shales. It is perhaps for this reason that no conglomerates are found in the Jurassic there.

Away from the Tyers River the conglomerate loses its massive character and thicker softer sandstones are present in the sequence. Along Rintoul's Creek, in the upper 70 ft. of the formation, 50 ft. of non-conglomeratic sediments, which include cross-bedded creamy-buff sandstones with minor grits, grey and brown mudstones and a thin coal seam, are present. Grits and sandstones with minor amounts of mudstones are present elsewhere lower down in this sequence and in all constitute over half the total thickness of the formation. Along Anderson's Creek the proportions are similar. Here, also, as at the base of the conglomerate at Rintoul's Creek, the conglomerates tend to have a clayey matrix. In all other localities, however, the conglomerate has a highly siliceous cement. Overall, the conglomerates exposed along Rintoul's Creek and Anderson's Creek contain smaller cobbles than those of the Tyers River.

In length the Tyers Conglomerate is lenticular. At the cliffs along the Tyers River there is exposed a total thickness of about 390 ft. of massive conglomerate. To the west along Anderson's Creek, 178 ft. of conglomerate was present in a measured section. Further westward at Yallourn North the Tyers Conglomerate at the base of the section is only 30 ft. thick.

East of the Tyers River 335 ft. of conglomerate is present in the section along Rintoul's Creek, although, surprisingly, conglomerates are completely absent along Stony Creek where Jurassic sandstones directly overlie the Siluro-Devonian basement rocks. Further east at Eaglehawk Creek, beds of conglomerate up to 3 ft. thick are present in a very condensed section, in all totalling 66 ft. of exposed sediments.

The lensing towards the basin is more difficult to establish. It is best seen in a comparison between the section measured along the Tyers River where 237 ft. of conglomerate is present and the start of the section where there is 390 ft. of

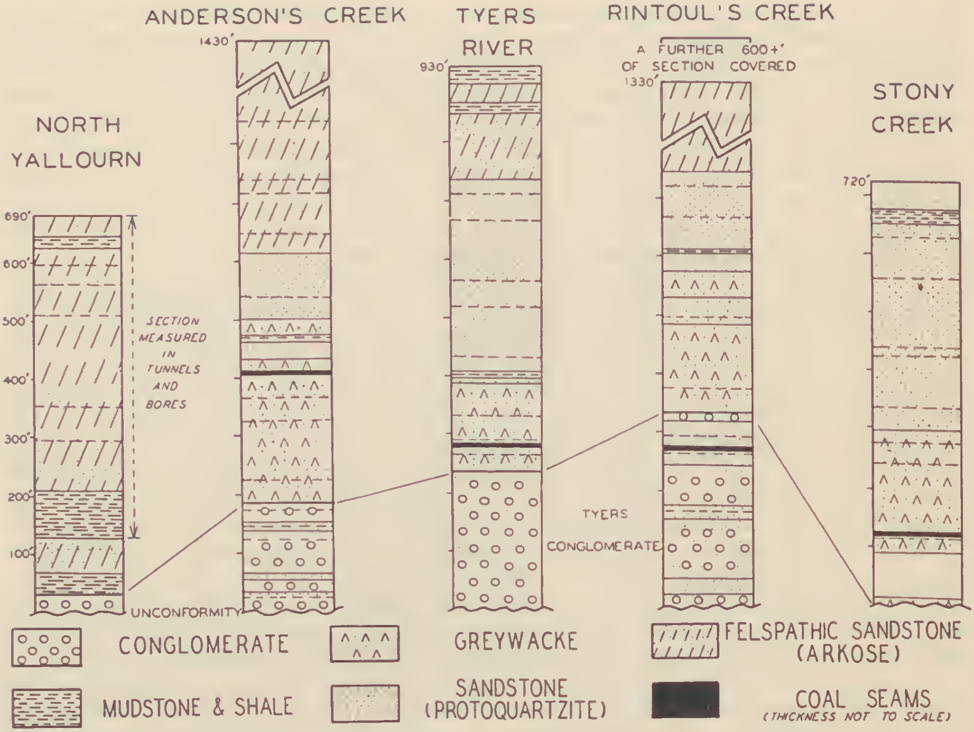

FIG. 2.—Generalized stratigraphic sections through the Tyers Group, showing the distribution of the dominant rock-types.

conglomerate in the river cliffs. This suggests that the conglomerate lenses out basinwards within a mile from its present base exposed along the Tyers River, whereas it persists along the strike at least 10 miles. Thus the conglomerate is wedge-shaped and conforms to a "fanglomerate" of Lawson (1925)—bodies characterized by a considerable persistence parallel to the edge of the basin but a rapid lensing basinwards. Such conglomerates are envisaged as marginal accumulations of detritus derived from sharply uplifted highlands.

The conglomerates are strongly cross-bedded. Some cross-bed units exceed 4 ft. but many are thinner. The cross-bedding is more apparent where sands are interbedded with the conglomerates. Exposures did not lend themselves to the study of the orientation of the cross-beds and only in two localities was it possible to compile enough measurements (see p. 193). Within the cross-bedded units the pebbles show a marked orientation (see p. 194).

The sandstones interbedded with the conglomerates are very similar to sandstones higher in the sequences. They are medium- to coarse-grained weathered creamy-buff sandstones containing essentially subangular to subrounded grains of quartz with occasional sedimentary rock fragments and weathered felspars. Detrital matrix is present but constitutes less than 8 per cent of the rock. This matrix consists essentially of finer-grained quartz and a little sericite. Where the rock is lithified it is cemented by authigenic overgrowths of secondary silica in the places where the

quartz grains are in contact. Table 2 shows the micrometric analysis of such a sandstone from Anderson's Creek. Their good sorting attests to the strong winnowing action by currents before their ultimate deposition.

Noteworthy is the pitting of many of the conglomerate pebbles, particularly where the bulk of the conglomerate is made up of fine-grained greywacke in the localities where little or no matrix or cement is present. The best locality examined was on the east side of the Tyers River toward the top of the cliff section there exposed.

The term "pitted pebble" is generally applied to pebbles and cobbles which possess marked concavities apparently due in some way to contact with adjacent pebbles. The pitting in the pebbles of the Tyers Conglomerate is confined to the more disc-shaped pebbles of the softer rock types present. The concavities are smooth and may be up to 6 in. across and include almost the whole surface of a pebble. A group of typical pitted greywacke pebbles is illustrated in Pl. XXX, figs. 4 and 5.

Such phenomena have been attributed variously to mutual indentation by pressure, and solution induced by pressure at points of contact of the pebbles. Kuenen (1942), reviewing the literature on pitted pebbles, considered the idea of mutual indentation by pressure untenable. He states (p. 189), "The most obvious explanation, that of mutual indenture by pressure is easily withlain [*sic*]. Two pebbles squeezed in a vice will always fracture before denting each other. The material squeezed from an indenture should form a ridge around the pit, but normally the pebbles are smooth." Kuenen thus concludes that the only valid mechanism in the formation of pitted pebbles is by solution at points of pressure.

The pitting in pebbles from Tyers appears to have been brought about by mutual indentation in a way not covered by Kuenen's analogy. The flatter pebbles are structurally less able to withstand deformation than the more rounded pebbles. Thus a flattened pebble, supported underneath marginally by two rounded pebbles and centrally supporting another rounded pebble, in response to pressure on compaction

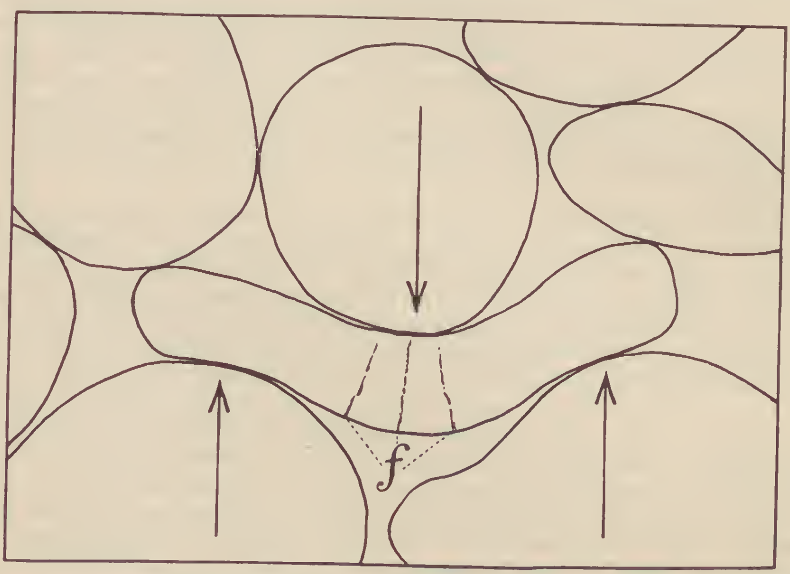

FIG. 3.—Schematic representation of the manner in which the "pitted" or "deformed" pebbles in the Tyers Conglomerate are produced, as a response to compaction. f = fissures.

tends to be deformed and wrap itself around the structurally stronger pebbles (Fig. 3). Moreover, all the pebbles of soft greywacke which show significant pitting also show concomitant fissuring along the zone of greatest deformation. It is concluded then that the pitting in these pebbles was caused by compaction. Such pebbles possibly should be described as "deformed pebbles" rather than "pitted pebbles".

(B) Greywackes

Immediately overlying the conglomerates and forming a significant part of the sequence is a group of massive sandstones which are here classified as greywackes. They are typically creamy to buff in colour although the finer-grained members particularly can be quite rich in carbonaceous material, when they are grey. They usually show cross-bedding, often on a very fine scale. Penecontemporaneous slumping is present toward their base along Rintoul's Creek. Their upper limit is difficult to define as they grade into well-sorted sandstones in which the detrital matrix has become subordinate. Their relative thickness in each of the stratigraphic sections can be seen in Fig. 2.

In thin section these Jurassic greywackes are medium to fine grained and poorly sorted, the grain sizes ranging from 0·5 mm. downwards. The grains are essentially angular to subangular quartz with minor amounts of more rounded fragments of fine-grained sedimentary rock. Felspar is virtually absent. Small bent flakes of detrital mica are present, together with occasional well-rounded zircons and tourmalines. The matrix, which may constitute up to 45 per cent of the rock, consists of finer quartz fragments and sericite stained by limonite. Fragments of coalified plant remains occur throughout the rock. Higher in the sequence there is less matrix in the greywackes. Clearly both in hand specimen and thin section these Jurassic greywackes match the Siluro-Devonian greywackes which outcrop to the north, and which, as has been pointed out, make up most of the cobbles of the conglomerates (cf. Pl. XXIX, figs. 2, 3). Micrometric analyses of both these rock types are shown in Table 2. They can be seen to be remarkably similar in mineral composition.

Interbedded with the greywackes are normal mudstones and shales. In places, as along the Tyers River, seams of black coal up to 3 in. thick are also present. Grits occur throughout the greywackes but are rarer towards the top. Some of these may show grading on a minor scale. In general they consist of subangular grains of vein quartz and sedimentary rock fragments up to 3 mm. in size, again set in a fine-grained matrix.

There is a virtual absence of labile constituents in the greywackes. Typical greywackes contain a considerable percentage of felspars and/or rock fragments. Fischer (1933) has suggested the term "quartz-wacke" for a greywacke in which the stable constituents make up more than 90 per cent of the rock. The "quartz-wacke" of Fischer is virtually synonymous with the "low-rank greywacke" of Krynine (1945) and the "subgreywacke" of Pettijohn (1949). The Siluro-Devonian greywackes, as well as these Jurassic greywackes conform to sandstones of this class. In the field these rocks can be readily distinguished from the normal Jurassic basin sandstones because of their colour. As has already been stated the normal felspathic sandstones are greeny-grey in colour when fresh, and weather to brown, the colour being due to the chloritic cement. The greywackes, on the other hand, are creamy-buff. The difference is due to the fact that the greywackes being packed tight with detrital material (or "paste") were impermeable to the solutions which deposited the chloritic cement in the "clean" felspathic sandstones. In the protoquartzites (see below) which overlie the greywackes, although the detrital matrix is subordinate, secondary silica has cemented much of the rock, preventing any influx of chlorite cement. To-

ward the top of these sandstones, however, they may take on the characteristic colour of the felspathic sandstones due to some introduced chlorite.

TABLE 2

Micrometric Analyses of Greywackes and Protoquartzites

Constituents	1	2	3	4
Quartz	51·7	49·4	68·5	69·8
Felspar	tr.	tr.	tr.	—
Sedimentary rock fragments	1·7	1·5	3·3	2·8
Secondary quartz and voids	—	2·5	13·9*	19·3
Minor detrital minerals†	3·4	2·2	0·5	tr.
Matrix	43·2	44·4	13·8	8·1

* Including introduced chlorite.
† Including carbonaceous material.

1. Siluro-Devonian greywacke, section cut from a pebble taken from the Tyers Conglomerate.
2. Typical Tyers Group greywacke, collected 470 ft. above the base of the section along Anderson's Creek.
3. Tyers Group protoquartzite, from 430 ft. above the base of the section along Tyers River.
4. Protoquartzite interbedded with conglomerate near base of section along Anderson's Creek.

(C) SANDSTONES (PROTOQUARTZITES)

The Jurassic greywackes pass up into well-sorted sandstones again showing marked cross-bedding. These may be creamy-buff through to greeny-brown in colour. Their relative thickness in each measured section is seen in Fig. 1.

In thin section they are seen to be medium-grained sandstones made up essentially of subangular to subrounded grains of quartz with very minor amounts of sedimentary rock particles and detrital matrix (Pl. XXIX, fig. 5). Authigenic overgrowths of quartz are present around many of the quartz grains, giving a false impression of angularity. The minor amounts of matrix present in the rock consist of fine quartz and sericite often stained by limonite, perhaps derived from the weathering of chlorite, traces of which are still present in the rock. A micrometric analysis of one such typical sandstone is given in Table 2.

Locally these sandstones may contain small pockets of fine conglomerates with grains up to 7 mm. across. They consist of well-rounded fragments of fine-grained sedimentary rock and occasional large angular grains of quartz set in a matrix of normal sandstone. One such conglomerate from the Tyers River is illustrated in Pl. XXX, fig. 4.

This sandstone agrees with Pettijohn's "protoquartzite", which is the more quartz-rich member of the lithic sandstone family. Here they represent "washed" greywackes formed by the elimination of the fine interstitial matrix which is so abundant in the greywackes. Such sandstones here were taken to reflect a period of decreased rate of subsidence of the basin, permitting more prolonged winnowing.

(D) FELSPATHIC SANDSTONES (ARKOSES)

At the top of the sections exposed from North Yallourn to Rintoul's Creek (Fig. 2) are felspathic sandstones proper of the Jurassic as described earlier in this paper. In the field they are dark in colour and are speckled brown to greenish-brown where they are fresher. Again they are cross-bedded but not as strongly as the sediments lower down in the sequence. These sandstones contain the characteristic andesite or andesitic tuff fragments together with felspars—the usual detrital components of the sandstones. Toward the top of the sequence they are indistinguishable

from the normal arkoses from elsewhere in the Jurassic (see Table 1). These rocks are taken to represent material originally derived from the same general source as the great bulk of the Jurassic of Victoria, here brought in by current action and mixed with quartz derived from the highlands to the north. Cross-bedding studies (see later) suggest that high in the sequence the current direction became much more variable and was in part directed from the basin.

(E) Other Sediments

Normal mudstones and shales are interbedded with the sandstones. They weather to a brown colour but those rich in carbonaceous material remain a grey colour. Typically they are very fine silts with small angular fragments of quartz in a very fine matrix of sericite and clay. Shredded carbonized plant remains are abundant in most sections.

In places throughout the Tyers Group occur very thin seams of black bituminous coal usually only about two to three inches thick. These are apparently drift in origin as they are similar in occurrence to the other coals throughout the Jurassic sequence. They do not appear to be confined to any one horizon but are distributed sporadically through the sequence. The thickest coal seam within the Group outcrops in a small tributary of Anderson's Creek near the Anderson's Creek Fault. This seam is at least eight inches thick but is almost impossible to trace along the strike. The occurrence of the more important seams is shown in Fig. 2.

Intraformational conglomerates are present but not common in the sequence. They occur directly overlying the Tyers Conglomerate at North Yallourn, and are present at the top of the sections along the Tyers River and Anderson's Creek. Typically they consist of angular to subrounded fragments of mudstone set in a sandstone matrix. They apparently represent contemporaneous erosion of softer mudstone (Edwards and Baker, 1943).

Fossil Flora

No plant determinations have been recorded from the Tyers Group although Murray (1876, p. 141) notes the occurrence "of plant impressions similar to those in other portions of the mesozoic series" within the Tyers Conglomerate. Fragmentary plant remains and carbonized wood occur through much of the sequence but are much more common towards the top. *Taeniopteris spatulata* is by far the most abundant of the recognizable leaf impressions. The best-preserved plant remains in the sequence occur in grey silty greywackes along Rintoul's Creek about 450 ft. above the base of the section. Here the flora is represented by:

Taeniopteris spatulata
Taeniopteris crenata
Elatocladus mccoyi
Elatocladus cf. *conferata*
Sphenopteris (?) sp.

This flora is typical of that of the Victorian Jurassic sequence as a whole, regarded by Medwell (1954) as indicative of a Lower Jurassic age (with the exception of the Merino Group).

Source Rocks

The study of primary current structures within sediments has become standard practice in an analysis of current directions and possible source areas. Two such features were used in the Tyers Group—the first, cross-bedding; and the second, pebble orientation within the Tyers Conglomerate.

(A) Cross-bedding

McKee and Weir (1953) have attempted to classify cross-bedding on the basis of the arrangement of the cross-laminations. The cross-bedding within the Tyers Group conforms generally to their "simple" type (i.e. those in which the lower bounding surface of the sets is non-erosional) but "planar" types (those in which the lower surface is erosional) are not uncommon. It is doubtful whether classifications of this sort have any genetic significance and so their usefulness is open to question. The cross-bedded units are up to 4 ft. in thickness in the Tyers Conglomerate, but in the sandstones higher in the sequence they are of the order of 2 ft. or less.

Apart from the widespread use of cross-bedding orientation in locating possible source areas for cross-bedded strata (e.g. Potter and Siever, 1956) their study has been used for fixing the trend of ancient shore lines (Tanner, 1955).

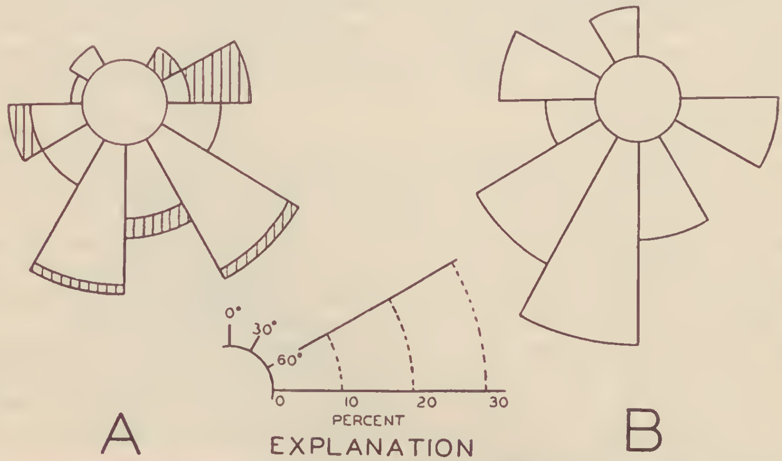

Fig. 4.—Cross-bedding azimuth distribution in the Tyers Group. A, 68 cross-bed measurements along Rintoul's Creek. The shaded area represents 14 of these measured above 750 ft. from the base of the section. These indicate a change in current direction to in part directed from the basin. B, 15 cross-bed measurements from Eaglehawk Creek.

In two places within the Tyers Group exposures were good enough to measure the orientation of a sufficient number of cross-beds. Even so, at one of these localities, only 15 cross-bed units were measured.

The procedure was to measure the strike and dip of the top of a cross-bed, either directly, or by calculating its true dip from two apparent dip readings. These were then adjusted for the tilt of the strata by appropriate rotation of the cross-bedded plane about the strike of the true bedding. The dip direction of each of the cross-bed surfaces was thus found and the data summarized in conventional "rose" diagrams.

Along Rintoul's Creek 68 cross-bedding measurements were made. Their orientation is shown in Fig. 4A. These have been arbitrarily divided into two groups, 54 measured in the lower 750 ft. of the section and 14 in the upper 600 ft. The lower 54 show a prevailing southerly dip of the cross-laminations and are taken to indicate that the sandstones and conglomerates in which they were measured were derived from the highlands to the north. The final 14 measured in the upper 600 ft. of the section show a marked increase in variability in cross-bed orientation. They are hardly sufficient in number to be really significant, but as they can be correlated

with the entry of new detrital elements in the sandstones (andesite fragments and felspars), they are taken as indicative of a change in current direction to one in part directed from the basin bringing in the characteristic clastic debris of the Jurassic sandstones proper.

In the small section exposed along Eaglehawk Creek, 15 cross-bed measurements were made (Fig. 4B). Although again these are hardly enough to be significant they show a marked indication that these sediments were derived from the north.

(B) Conglomerate Fabric

A quantitative approach to the study of the orientation of pebbles in conglomerates and tills was introduced by Richter (1932). By studying the preferred shape orientation of the pebbles in a till, the plan of ice movements over a large area was reconstructed. Since then the study of pebble orientation in rudaceous rocks has become widespread. The technique consists of measuring the azimuth and dip of the long axes of a large sample of pebbles within a conglomerate bed. The observations are then usually represented on a stereographic diagram which may be contoured. Here the axes have been shown as a lower hemisphere plot and contoured with the aid of a "Schmidt" equi-area net.

Schlee (1957), working in recent fluvial gravels, showed that highly significant results may be obtained by plotting the orientation of as few as twenty pebbles by selecting pebbles of a characteristic shape, i.e. ones more likely to be oriented by current action during deposition. He plotted the orientation of the longest axis of "rod-shaped" pebbles and the shortest axis of "disc-shaped" pebbles on separate diagrams. For the placement of these axes see Krumbein, 1941. By eliminating the more spherical pebbles whose orientation may be almost at random to the main current direction the fabric of the gravel became much clearer.

Cailleux (1945) notes that the smallest pebbles in a gravel are oriented more by contact with larger pebbles than by current action. Consequently, in describing fabrics, he used pebbles larger than 4 cm. in length. White (1952) also found that in a bed of Keeweenawan conglomerate the smaller pebbles (less than 2 in. in length) were more randomly disposed than the larger pebbles.

For these reasons, in examining the fabric of the Tyers Conglomerate, only the orientation of the larger "rod-shaped" and "disc-shaped" pebbles was investigated. To avoid the obvious personal bias which could arise from such restricted sampling, the "rod-shaped" and "disc-shaped" pebbles were defined in terms of their axial lengths. Also only pebbles with their longest axis greater than 6 cm. were taken from the first locality studied, and those whose longest axis exceeded 10 cm. from the second locality. These figures approximate to the lower limit of the upper quartile of the size distribution in each case. The pebbles in the first locality were taken from a predetermined area of outcrop.

The "disc-shaped" pebbles were defined as those pebbles in which $c \leqslant \frac{1}{2} b$, while "rod-shaped" were those in which $c > \frac{1}{2} b$ and $a \geqslant b + c$. (a, b, and c are the axial dimensions of the pebbles in the longest, intermediate, and shortest directions—see Krumbein, 1941.) Although these definitions are slightly at variance with existing shape classifications of pebbles (Zingg, 1935; Harrison, 1957), they are much more simple to apply. No provision has been made for the "blades" of Zingg as no really bladed pebbles were present in the conglomerate. Most pebbles in the conglomerate fall within the above categories because of their low sphericity.

Because of the widespread siliceous cement, it was possible to study the fabric of the conglomerate in two localities only. The first was on the spur along which runs the Erica-Traralgon road. Here the conglomerate was weathered and the pebbles could be easily removed from the matrix. The orientation of 48 rod-shaped

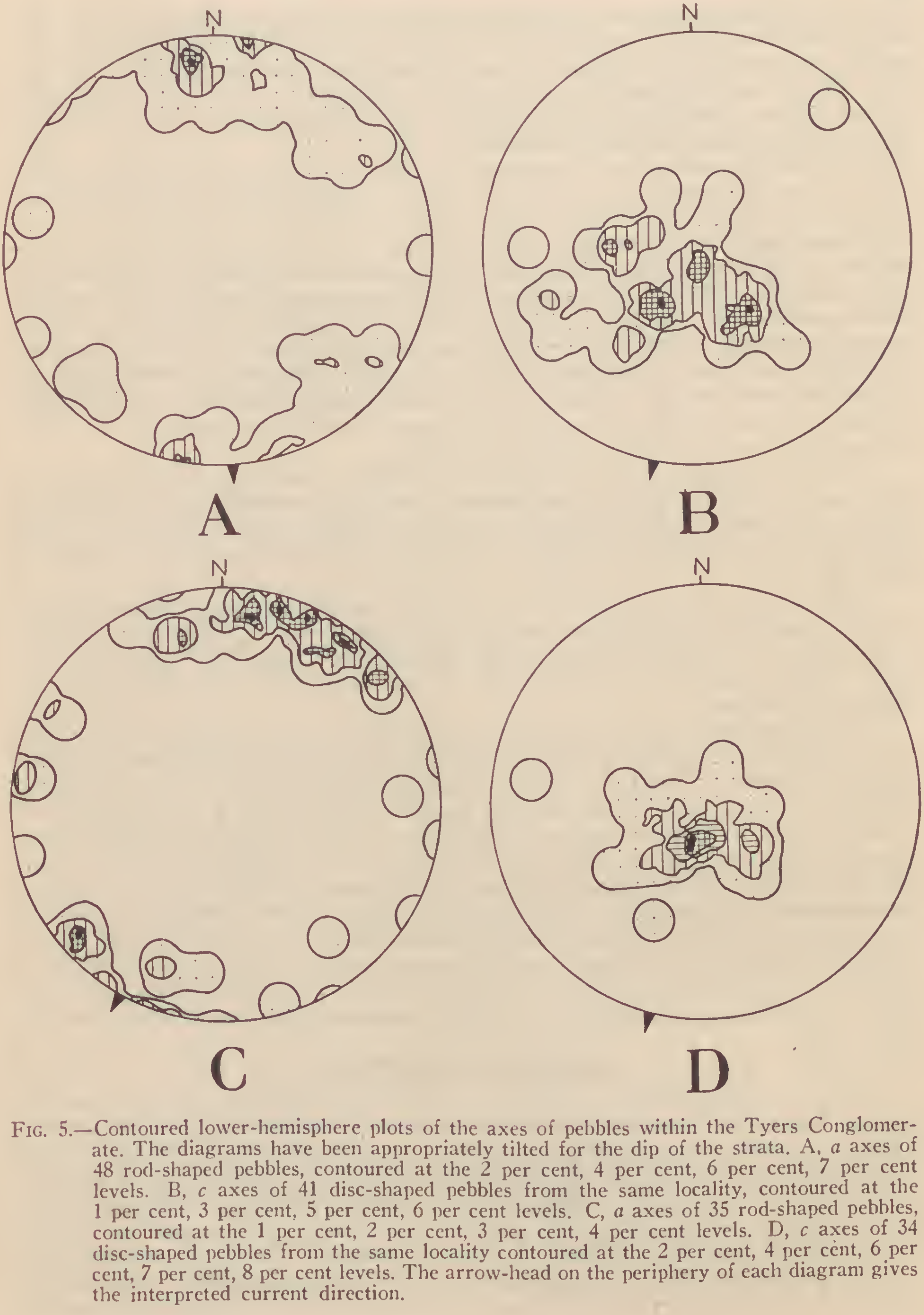

FIG. 5.—Contoured lower-hemisphere plots of the axes of pebbles within the Tyers Conglomerate. The diagrams have been appropriately tilted for the dip of the strata. A, *a* axes of 48 rod-shaped pebbles, contoured at the 2 per cent, 4 per cent, 6 per cent, 7 per cent levels. B, *c* axes of 41 disc-shaped pebbles from the same locality, contoured at the 1 per cent, 3 per cent, 5 per cent, 6 per cent levels. C, *a* axes of 35 rod-shaped pebbles, contoured at the 1 per cent, 2 per cent, 3 per cent, 4 per cent levels. D, *c* axes of 34 disc-shaped pebbles from the same locality contoured at the 2 per cent, 4 per cent, 6 per cent, 7 per cent, 8 per cent levels. The arrow-head on the periphery of each diagram gives the interpreted current direction.

and 41 disc-shaped pebbles was measured here. The results are summarized in Fig. 5A and B. The *a* axes of the rod-shaped pebbles show a well-developed 7 per cent maximum trending a few degrees west of north, and dipping northward at 12°, with a 5 per cent submaximum trending a few degrees east of north. The disc-shaped pebbles on the other hand show two 6 per cent maxima with the *c* axes dipping southward at an angle of about 65°.

When the measurements were being made it was suspected that pebbles from two cross-bedded units were being used, which is further borne out by the presence of the two maxima.

In the extensive cliff sections on the east side of the Tyers River it was apparent that the conglomerates were deposited in large-scale cross-beds. For this reason the orientation of pebbles was measured over a considerable area of outcrop. The orientations of 35 rod-shaped and 34 disc-shaped pebbles were measured. The results are summarized in Fig. 5C and D. The *a* axes of the rod-shaped pebbles here show a series of four maxima distributed in the north-east quadrant of the diagram and the pebbles tend to dip northwards. The disc-shaped pebbles have their *c* axes grouped around an 8 per cent maximum dipping steeply southwards. A 6 per cent submaximum nearby shows a similar disposition.

The most extensive study of the subject of pebble orientation within gravels has been made by Schlee (1957). For fluvial gravels he established that rod-shaped pebbles are oriented subparallel to the current direction and dip up-stream while the *c* axes of the disc-shaped pebbles tend to dip down-current at a high angle of about 70°.

Thus the data indicates that in the localities investigated the current direction was from the north. Fig. 5 shows the *a* axes of the rod-shaped pebbles to be dipping at an average of about 15° to the north, indicating that the current was from the north. This is again borne out by the inclination of the *c* axes which should be dipping down-current.

The conglomerates do not show such marked preferred orientation of the pebbles as the gravels investigated by Schlee. This is to be expected as they are not fluvial in origin. Another difference is that the Tyers Conglomerate has been compacted which in this case has deformed many of the pebbles and so altered their orientation.

Thus primary current features support the conclusion that the conglomerates, greywackes and sandstones of the Tyers Group were derived from the highlands to the north where the source rock was mainly greywacke. This conclusion is further substantiated by the matching of rock types within the Tyers Conglomerate and the mineralogical similarity between the sandstones of the Tyers Group and the Siluro-Devonian greywackes. The entry of the normal detrital elements characteristic of the bulk of the Jurassic sandstones is taken to represent material derived from elsewhere which has been brought in from the basin and mixed with sands from the local source.

Conditions of Sedimentation

The Tyers Conglomerate represents a marginal accumulation of coarse detritus derived from the highlands to the north which had apparently been strongly uplifted. The low sphericity of the pebbles, as well as the poor rounding of the harder rock fragments is taken to indicate short distance of transport before burial. In composition it is a typical polymictic conglomerate, composed essentially of rock types prone to weathering, and deposited under conditions of heavy sedimentation with strong current action (as shown by the large-scale cross-beds) in a rapidly sinking basin.

The greywackes above the conglomerates also indicate conditions of rapid sedimentation. Greywackes are typically geosynclinal sediments showing graded bedding

and strongly characteristic of this tectonic environment. It is noteworthy that here they are cross-bedded. They are present in this limnic environment apparently because of two reasons—first, because greywackes constitute their source (they could well be regarded as second-cycle greywackes), and, secondly, because rapid sedimentation and burial accompanied their deposition. This rapid burial is further indicated by the fact that the best-preserved plant remains in the series occur within these sediments. That the current action was not so strong as in the conglomerates is indicated by the smaller cross-bedded units.

The sandstones (protoquartzites) above the greywackes indicate an approach to the stable conditions of sedimentation under which the remainder of the Tyers Group was deposited. They in fact represent "washed" greywackes in which the detrital matrix has been removed by current action. Overall these well-sorted sediments indicate very mild subsidence during accumulation and considerable transport and winnowing action before final consolidation. It was under such conditions that the rest of the Jurassic sequence of Victoria was deposited. Burial was, however, fairly rapid in the normal felspathic sandstones, as the felspars in this rock are remarkably fresh.

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Explanation of Plates

Plate XXIX

All slides studied are lodged in the thin section collection of the Department of Geology, University of Melbourne, except those lent to the author by Dr. A. B. Edwards.

Photomicrographs of—

Fig. 1.—Typical Jurassic felspathic sandstone (arkose) from Griffith's Point, San Remo Peninsula. Note the dark well-rounded fragments of weathered andesitic glass, and the mottled fragments of fresher andesite. Felspar is present as the slightly opaque grains, whereas quartz is represented as the clear angular to subrounded fragments. The grains have been first cemented by a thin film of zeolitic material of low refractive index now clearly seen in the section outlining the grains. The rest of the spaces between the grains is filled with chlorite cement and in some of the larger interspaces voids have been left. Matrix is virtually absent. Plane polarized light. × 36. (Slide by courtesy of Dr. A. B. Edwards.)

Fig. 2.—Fine-grained Siluro-Devonian greywacke; section of a pebble taken from the Tyers Conglomerate. This rock consists of angular to subangular quartz grains set in a matrix of sericite and finer quartz. These poorly sorted geosynclinal sandstones constitute the local source of the Tyers Group. Nicols half crossed. × 36.

Fig. 3.—Jurassic greywacke from Anderson's Creek. This rock is mineralogically and texturally indistinguishable from the Siluro-Devonian greywacke which constituted its source. Nicols half crossed. × 36.

Fig. 4.—Jurassic conglomerate collected 430 ft. above the base of the section along the Tyers River. This occurs as small pockets within the Jurassic sandstone which makes up its matrix. It consists of angular quartz fragments and rounded fragments of Siluro-Devonian mudstone. Plane polarized light. × 9.

Fig. 5.—Jurassic sandstone (protoquartzite) from the Tyers River. Note that the detrital matrix is now subordinate. This rock represents a "washed" greywacke, produced by the elimination of the matrix. The grains show much better rounding than in the greywackes, although a false impression of angularity is given by authigenic overgrowths of the quartz grains. Two such overgrowths are clearly visible in the top right-hand corner of the figure. This rock is the matrix present in the conglomerate shown in fig. 4. Nicols half crossed. × 36.

Plate XXX

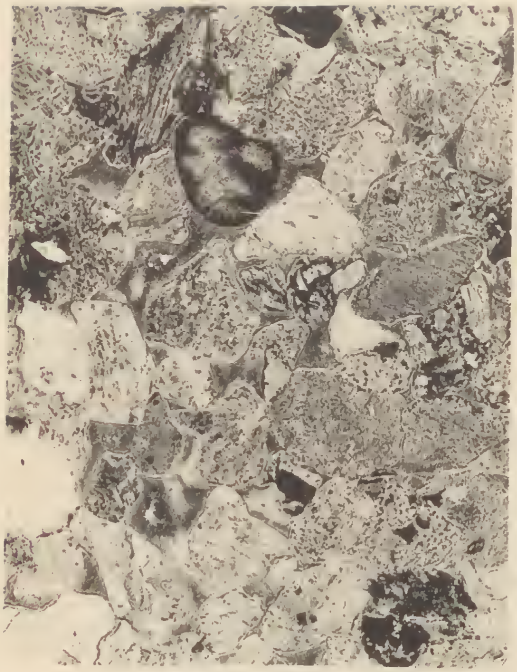
Fig. 1.—Massive Jurassic sandstones (protoquartzites) interbedded with mudstones along Anderson's Creek.

Fig. 2.—Strongly cross-bedded Jurassic sandstones (protoquartzites) exposed in Rintoul's Creek.

Fig. 3.—Typical exposure of the Tyers Conglomerate on the east side of the Tyers River, where cement is absent and the matrix is of unlithified sand. Note the marked imbrication of the pebbles.

Fig. 4.—Group of "pitted pebbles" from the Tyers Conglomerate collected from the locality illustrated above. Note the fissuring present. Lit from the top left. × $\frac{1}{4}$ approximate.

Fig. 5.—Other side of same group of pebbles. × $\frac{1}{4}$ approximate.



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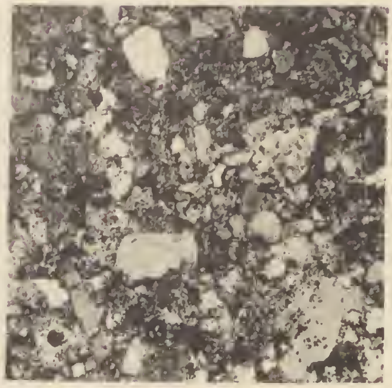

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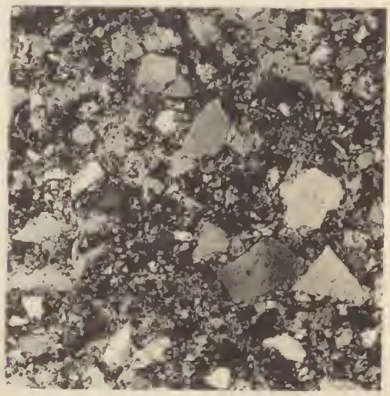

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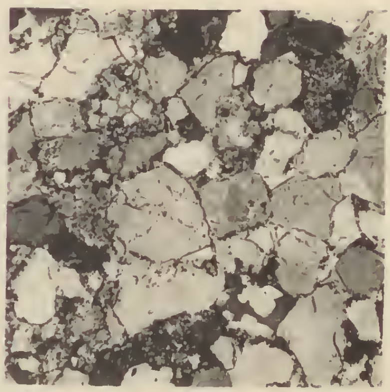

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Clifford, H. T., M.Sc., University College, Ibadan, Nigeria 1949
Clinton, H. F., "Whitehall," 20 Bank Place, Melbourne, C.1 1920
Coats, R. P., B.Sc., Mines Department, Adelaide, South Australia 1951
Cobbett, A. M., Oxford Close, Moorabbin 1951
Cochrane, G. W., M.Sc., c/o B.H.P., 422 Little Collins Street, Melbourne, C.1 1945
Collins, A. C., 9 Olympic Avenue, Newtown, Geelong 1928
Cookson, Dr. I. C., D.Sc., 154 Power Street, Hawthorn, E.2 1919
Court, A. B., Childs Road, Kalorama 1949
Crespin, Miss I., B.A., F.R.M.S., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1919
Crohn, P. W., M.Sc., 29 Kensington Road, South Yarra, S.E.1 1946
Currey, D. T., 15 Maple Crescent, Camberwell, E.6 1948
Davies, Mrs. E. M., 392 Balcombe Road, Beaumaris 1956
Dempster, Miss P. B., B.Sc., Commerce Department, University, N.3 1957
Dettmann, Miss M. E., B.Sc., Botany Department, University, N.3 1957
Douglas, J. G., B.Sc., 35 Valley Parade, Glen Iris, S.E.6 1957
Down, Mrs. Mary R., B.Agr.Sc., 35 Durham Street, Heidelberg, N.22 1942
Dunn, R. A., A.A.A., A.A.I.S., 60 Mimosa Road, Carnegie, S.E.9 1946
Edwards, G. R., B.Sc., 115 Grey Street, Traralgon 1937
Elford, F. G., B.Sc., B.Ed., 76 New Street, Brighton, S.5 1929
English, J. R., 302 Lower Heidelberg Road, East Ivanhoe 1956
Esplan, W. A., 37 Barnes Avenue, Burwood, E.13 1951
Finlay, Miss C. F., B.Sc., Geology Department, University, Carlton, N.3 1950
Fisher, Eileen E., Ph.D., 1 Balwyn Road, Canterbury, E.7 1949
Frostick, A. C., 9 Pentland Street, North Williamstown, W.16 1933
Gaskin, A. J., M.Sc., 1110 White Horse Road, Box Hill, E.11 1941
Gladwell, R. A., 23 Turnbull Ave., Toorak, S.E.2 1938
Gordon, Alan, B.Sc., c/o P.O. Box 14, Tokoroa, New Zealand 1938
Goudie, A. G., B.Agr.Sc., Tatura 1941
Gunson, Miss Mary, M.Sc., Zoology Department, University, Carlton, N.3 1944
Hauser, H. B., M.Sc., Geology Department, University, Carlton, N.3 1919
Haycroft, J. A., c/o Western Mining Corp. Ltd., 55 MacDonald Street, Kalgoorlie, W.A. 1951
Head, W. C. E., 56 Lynch Street, Yarrawonga 1931
Heysen, Mrs. D., P.O. Box 10 Kalangadoo, South Australia 1935
Hogan ,T. W., M.Agr.Sc., 25 Devon Street, Box Hill South, E.11 1947
Holdaway, E. A., B.Sc., 11 Leopold Crescent, Mont Albert, E.10 1957
Holland, R. A., 526 Toorak Road, Toorak, S.E.2 1931
Holmes, A. J., 92 Latrobe Street, Warragul 1949
Honman, C. S., B.M.E., 3 Fairy Street, Ivanhoe, N.21 1934
Hounslow, A. W., Mineragraphic Section, C.S.I.R.O., University, N.3 1958
Jack, A. K., M.Sc., 49 Aroona Road, Caulfield, S.E.7 1913

Jones, D. Spencer, B.Sc., 31 Winmalee Road, Balwyn, E.8 1952
Jones, K. A., B.Com., 28 Scott Street, Beaumaris 1956
Jones, L. H. P., M.Sc., Ph.D., School of Agriculture, University, Carlton, N.3 1948
Kenley, P. R., B.Sc., 88 Willis Street, Hampton, S.7 1948
Kenny, J. P. L., B.C.E., 38 College Street, Elsternwick, S.4 1942
Learmonth, A. P., B.Sc., Mines Department, Melbourne, C.2 1955
Lindner, A. W., B.Sc., c/o West Australian Petroleum Pty. Ltd., Box L 898, G.P.O., Perth, W.A. 1949
Lord, E. E., 77a Durham Road, Surrey Hills, E.10 1950
McLennan, Assoc. Prof. Ethel, D.Sc., University, Carlton, N.3 1915
McNally, J., B.Sc., 3 Arcadia Street, Box Hill, E.11 1950
Macpherson, Miss J. Hope, M.Sc., National Museum, Russell Street, Melbourne, C.1 .. 1940
Marsden, M. A. H., 68 Champion Street, Middle Brighton, S.5 1952
Mitchell, A. W. L., B.Sc., 77 Illawarra Road, Hawthorn, E.2 1946
Mitchell, S. R., 22 Grosvenor Street, Abbotsford, N.9 1945
Moore, B. R., B.Sc., Peter Street, Eltham 1957
Morris, P. F., National Herbarium, South Yarra, S.E.1 1921
Mulvaney, D. J., M.A., History Department, University, N.3 1957
Mushin, Mrs. Rose, M.Sc., Bacteriology Department, University, Carlton, N.3 1940
Neales, T. F., Ph.D., Botany Department, University, N.3 1957
Neilson, J. L., 1 Fordham Avenue, Camberwell, E.6 1952
Nicholas, T., 106 Nelson Road, Box Hill, E.11 1958
Nye, E. E., B.Sc., College of Pharmacy, 360 Swanston Street, Melbourne, C.1 1932
Oke, C., Mount Royal, Royal Park 1922
Philip, G. Maxwell, Geology Department, University, Carlton, N.3 1955
Philip, Mrs. J., Geology Department, University, N.3 1957
Pinches, Mrs. M., 140 Churchill Highway, Braybrook 1943
Pretty, R. B., M.Sc., Private Bag, Cobargo, N.S.W. 1922
Purnell, Miss H. M., M.Sc., Botany Department, University, N.3 1957
Rawlins, R. J., B.Sc., 1205 Dandenong Road, East Malvern, S.E.5 1957
Rigby, J. F., Holland Road, Blackburn 1953
Rimington, K. N., B.Sc., 15 Yuille Street, Brighton, S.5 1948
Rowney, George, B.Sc., 4 Riddle Street, Bentleigh, S.E.14 1952
Seeger, R. C., 56 Jenkins Street, Northcote, N.16 1946
Shaw, H., 30 Hoddle Street, Elsternwick 1956
Sherrard, Mrs. H. M., M.Sc., 43 Robertson Road, Centennial Park, N.S.W. 1918
Singleton, O. P., M.Sc., Ph.D., Geology Department, University, Carlton, N.3 1943
Stach, L. W., M.Sc., 78 Herbert Street, Albert Park, S.C.6 1932
Talent, J. A., M.Sc., Geology Department, University, Carlton, N.3 1955
Tylee, A. N., Jindivick North 1951
Vasey, G. H., B.C.E., University, Carlton, N.3 1936
Watts, H. A., 15 Tower Hill Road, Glen Iris, S.E.6 1954
White, D. A., B.Sc. (W.A.), Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. 1951
White, O. L., Geology Department, University, Carlton, N.3 1955
Whitehead, Mrs. R., c/o Ore Depot, B.H.P. Co. Ltd., Newcastle, N.S.W. 1942
Wymond, A. P., M.Sc., Division of Forest Products, C.S.I.R.O., P.O. Box 18, South Melbourne, S.C.4 1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1957

The President and Council present to members of the Society the Annual Report and Financial Statement for the year 1957.

The following meetings of the Society were held:

March 14.—Annual Meeting. The following office-bearers were elected: *President,* Mr. V. G. Anderson; *Vice-Presidents,* Associate-Professor G. W. Leeper, Mr. R. T. M. Pescott; *Honorary Treasurer,* Mr. L. Adams; *Honorary Librarian,* Associate-Professor C. M. Tattam; *Honorary Secretary,* Mr. Edmund D. Gill; *Members of the Council,* Mr. J. H. Chinner, Mr. P. Crosbie Morrison, Mr. E. R. Pitt, Dr. F. L. Stillwell, Dr. D. E. Thomas, Mr. A. G. Willis.

The following *Members of Council* continued in office: Mr. W. Baragwanath, Mr. D. A. Casey, Capt. J. K. Davis, Dr. R. R. Garran, Professor J. S. Turner, Professor Sir Samuel Wadham.

During the year Dr. C. M. Focken was elected to fill the vacancy on Council occasioned by the death of Mr. E. R. Pitt.

The Annual Report and Financial Statement for 1956 were received and adopted. At the close of the Annual Meeting an Ordinary Meeting was held. Lecture: "Genetics, the Science of Inheritance" by Dr. A. M. Clark.

April 11.—Lecture: "Recent Achievements by the A.N.A.R.E. in Antarctica" by Mr. P. G. Law.

May 9.—Lecture: "The Genesis of Brown Coal Gasification in Victoria" by Mr. Roy J. Bennie.

June 13.—Lecture: "New Research on Control of Weeds in Waterways" by Mr. A. L. Tisdall and Mr. W. P. Dunk.

July 11.—Papers: "Microplankton from Australian and New Guinea Upper Mesozoic Sediments" by Dr. Isabel C. Cookson and Professor A. Eisenack. "Fish Otoliths from the Tertiary Strata of Victoria, Australia" by Mr. F. C. Stinton. "The Palaeomagnetism of the Cenozoic Volcanics of Australia" by Mr. E. Irving and Mr. R. Green. Lecturette: "Palaeomagnetism" by Mr. E. Irving.

August 8.—Soirée, consisting of a reception, numerous exhibits, films of general scientific interest from five countries, and supper.

September 12.—Lecture: "The Murray Black Collection" by Professor S. Sunderland and Associate-Professor L. J. Ray.

October 10.—"Scientific Aspects of Trout Culture in Victoria" by Mr. J. C. F. Wharton.

November 14.—Lecture: "The Physics of Earth Satellites" by Dr. D. N. F. Dunbar.

December 12.—Papers: "Some Trilete Spores from the Upper Mesozoic Deposits in the Eastern Australian Region" by Dr. Isabel C. Cookson and Miss M. E. Dettman. "Fossil Woods from Victorian Brown Coals" by Dr. R. Patton. "Revision of the Genus *Diemeniana* (Cicadidae)" by Mr. A. N. Burns. "Larva and Pupa of an Australian Limnophelid (Trichoptera)" and "The Genus *Hepatesus* from the Austro-Malayan Sub-region (Elateridae, Coleoptera)" (read by title only) by

Mr. A. Neboiss. "Cliff Top Edges at Port Campbell" by Dr. G. Baker. "The Jurassic Rocks of the Tyers Group" by Mr. G. M. Philip.

Professor T. M. Cherry and Mr. D. A. Casey were appointed *Honorary Auditors.*

During the year 22 Members, 2 Country Members, and 14 Associates were elected. Two Associates resigned. The total membership of the Society at December 31, 1957, after revision, was 263.

The Council deeply regrets the loss by death of one Life Member, three Members, and one Country Member.

William Hamilton Ferguson died on July 28, 1957. His keen interest in natural history and his knowledge of parts of outback Victoria attracted the attention of the Mines Department, with whom he worked first in 1890 as a specimen collector and then as a field geologist, until he retired in 1926. He was the first curator of the Geological Survey Museum. He discovered Cambrian fossils near Heathcote, Lower Ordovician fossils at Boolarra, the Upper Ordovician at Lucyvale, the most westerly localities for the occurrence of graptolites in the State, and the fish and shell remains in the Grampians. Many gold-fields, including Dunolly, were surveyed by him, as well as parts of the South Gippsland coalfields. Mr. Ferguson belonged to this Society from 1894 till 1957.

Stanley Walton Gadsden died in July, 1957. Mr. Gadsden was a well-known industrialist, being Chairman of J. Gadsden Pty. Ltd., Australia and New Zealand. During the last war he was appointed by the Commonwealth Government to the Tinplate Board, and earlier was Chairman of the Commonwealth Advisory Committee on the use of radio on coastal vessels. In the early days of broadcasting, he was well known as an amateur broadcaster, and operated the first Victorian amateur station, 3SW. Mr. Gadsden was a generous donor to this Society, to which he was elected a member in 1954.

William John Harris, b.a., d.sc., dip.ed., died in Melbourne on June 26, 1957, at the age of 70 years. He joined the Education Department in 1902, was Headmaster of the Echuca High School for 20 years, and at the time of his retirement in 1952, was Headmaster of the Warragul High School. He was the author of several papers dealing with the geology not only of the regions where he lived, but also of the most inaccessible parts of the State, which he visited during his vacations. His chief interest, however, and the work for which he is best known, was his research work on Victorian graptolites and the zoning of the graptolite-bearing Ordovician and Silurian rocks. Dr. Harris published 23 papers on graptolites, mostly in collaboration with other workers. Thirteen of these were published in the *Proceedings* of this Society, of which he was a Country Member from 1914. He was a man of great integrity and untiring industry, well known not only to his past students throughout this State, but also to geologists throughout Australia and graptolithologists throughout the world. These he was ever ready to assist when required. He acted as Honorary Palaeontologist to the National Museum and to the Geological Survey, Mines Department, Victoria.

Albert Victor George James, b.a., d.sc., dip.ed., was born at North Fitzroy on August 1, 1882. On leaving school he joined the Education Department, in which service he remained until he retired in 1947. Studying at the University of Melbourne, he obtained First Class Honours in Geology, and was awarded the Dixon and Kernot Research Scholarships in that subject. Under their terms he carried out research in the Bulla-Sydenham area. The results were published in the *Proceedings* of this

Society and the *Journal of Geology* in U.S.A. While Headmaster of the Colac High School, he spent much of his spare time in field work on the surrounding basaltic areas. He was joined in this work by the late Professor Skeats, and the results were published in the *Proceedings* of this Society. Dr. James was widely known for his textbook on Geography, a modified edition of which was also used in New South Wales. Dr. James died on July 24, 1957.

Ernest Roland Pitt, B.A., F.L.A., was born at Strathloddon, near Guildford, Victoria, on October 16, 1877, was educated at St. Patrick's College, Melbourne, and graduated B.A. in 1910 at the University of Melbourne. He joined the staff of the Public Library of Victoria in 1900, and was Chief Librarian from 1931 until his retirement in 1943. His activities and interests were widespread. He was at various times President of the Library Associations of Victoria and of Australia, and of the Australian Public Service Federation, Chairman of the Joint Superannuation Committee, and later a member of the State Board, a member of the Representative Council of the Lawn Tennis Association of Victoria, and Victorian Secretary of A.N.Z.A.A.S. Mr. Pitt will be remembered for his part in the important Munn-Pitt Survey of Australian Libraries, 1934, and as editor of the C.S.I.R.O. Catalogue of Scientific and Technical Periodicals in the libraries of Australia. He became a member of this Society in 1946, and was elected to the Council in 1951. He died on June 28, 1957.

Attendances at Council Meetings were as follows: Mr. Adams, 7; Mr. Anderson, 9; Mr. Baragwanath, 9; Mr. Casey, 8; Mr. Chinner, 3; Capt. Davis, 8; Mr. Gill, 10; Assoc.-Professor Leeper, 8; Mr. Morrison, 4; Mr. Pescott, 3; Dr. Stillwell, 10; Assoc.-Prof. Tattam, 8; Dr. Thomas, 10; Prof. Turner, 1; Prof. Sir Samuel Wadham, 1; Dr. Garran, 4; Mr. Willis, 3; Dr. Focken, 4. Mr. Adams and Dr. Garran were granted leave of absence while overseas.

During the year 2,314 volumes and parts were added to the Library.

To assist the Honorary Secretary, Dr. F. L. Stillwell performed the duties of Honorary Editor.

HONORARY TREASURER'S REPORT

The year finished with a credit balance of £1,263/0/8. Of this sum, however, £200 represents the redemption of 200 Commonwealth Treasury Bonds in November, 1957, which now await re-investment.

There has been a considerable increase in the sale of *Proceedings* of the Society, and there has been a steady increase in the rents received.

The first interest from the F. A. Cudmore Estate has been received, and is being used to assist in the payment of an Assistant Librarian.

The Society again expresses its appreciation of the action of the State Government in maintaining its annual grant of £500 to the Society.

The Society desires also to record its thanks to the various donors who have made gifts and given assistance to the Society during the year.

L. Adams, *Hon. Treasurer*

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1957

RECEIPTS

Balance in Bank at 1/1/57		£402 11 10
Subscriptions—		
Members	£350 14 6	
Associate Members	207 18 0	
Country Members	46 4 0	
Arrears paid up	55 13 0	
Advance Subscriptions	25 15 0	
		686 4 6
Rents		186 12 6
Sale of Publications		536 16 7
Interest		87 8 2
Grants and Donations—		
State Government	£500 0 0	
K. Myer	26 5 0	
University of Melbourne	69 2 10	
A.N.Z. Association for the Advancement of Science	50 0 0	
		645 7 10
Sale of Bonds		200 0 0
Refunds		30 0 7
Sundries		11 6
		£2,775 13 6

EXPENDITURE

Salaries—		
Assistant Secretary	£30 0 0	
Assistant Editor	63 0 0	
Hallkeeper	94 4 6	
		£187 4 6
Printing Volume 69	£618 13 7	
General	177 2 7	
Reprints	71 5 0	
		867 1 2
Insurance		55 1 11
Electricity		127 8 4
Rates		27 10 0
Telephone		28 7 11
Postage		82 16 1
Repairs		89 6 5
Refreshments		20 6 0
Purchase of Journals		12 6 6
Stationery		1 12 6
Sundries		13 11 6
Balance in Bank at 31/12/57		1,263 0 8
		£2,775 13 6

L. ADAMS, *Hon. Treasurer.*

Audited and found correct,
24th February, 1958.

T. M. CHERRY, } *Hon.*
D. A. CASEY, } *Auditors.*

SPECIAL FUNDS

HALL FUND

Balance at 1/1/1957	£80 1 1	Balance at 31/12/1957	£82 5 1
Savings Bank Interest at 31/5/1957	2 4 0		
	£82 5 1		£82 5 1

LIFE MEMBERSHIP FUND

Balance at 1/1/1957	£200 0 6	Balance at 31/12/1957	£205 10 6
Savings Bank Interest at 31/5/1957	5 10 0		
	£205 10 6		£205 10 6

HOWITT MEMORIAL FUND

Balance at 1/1/1957	£170 13 6	Balance at 31/12/1957	£177 11 5
Interest on Bond	2 5 0		
Savings Bank Interest to 31/5/1957	4 12 11		
	£177 11 5		£177 11 5

SPECIAL FUNDS

T. S. HALL MEMORIAL FUND

Balance at 1/1/1957	£91 10 5	Balance at 31/12/1957	£94 0 6
Savings Bank Interest to 31/5/1957	2 10 1		
	£94 0 6		£94 0 6

BOOKBINDING FUND

Balance at 1/1/1957	£130 19 0	Balance at 31/12/1957	£134 10 6
Savings Bank Interest to 31/5/1957	3 11 6		
	£134 10 6		£134 10 6

Accounts and Pass Books relating to each of the above Funds, have been examined and found correct, and Bank receipts of possession of Bonds amounting to three hundred pounds (£300) and Savings Certificates to the face value of two hundred and fifty pounds (£250) have been inspected. Of the Bonds, one hundred pounds are to the credit of the Howitt Memorial Fund.

L. ADAMS, *Hon. Treasurer.*

Audited and found correct,
24th February, 1958.

T. M. CHERRY, } *Hon.*
D. A. CASEY, } *Auditors.*

SUMMARY FOR YEAR ENDING DECEMBER 31, 1957

Total Receipts	£2,373 1 8
Balance from 1956	402 11 10
	£2,775 13 6
Expenditure	1,512 12 10
Balance at Bank, 31/12/1957	£1,263 0 8

LIST OF THE INSTITUTIONS AND LEARNED SOCIETIES THAT RECEIVE COPIES OF THE PROCEEDINGS OF THE ROYAL SOCIETY OF VICTORIA

Argentine

Academia Nacional de Ciencias Exactas. Cordoba.
Sociedad Cientifica Argentine, Buenos Ayres.

Australia

Australian Forestry School, Canberra.
Bureau of Mineral Resources, Canberra.
Central Weather Bureau, Melbourne.
Commonwealth Bureau of Census and Statistics, Canberra.
Commonwealth Scientific and Industrial Research Organization, East Melbourne.
Commonwealth National Library, Canberra.
C.S.I.R.O. Division of Economic Entomology, Canberra.

Austria

Naturhistorisches Museum in Wein, Vienna.
Osterreichische Akademie der Wissenschaften, Vienna.

Belgium

Académie Royale des Sciences de Belgique, Brussels.
Institut de Botanique, Université de Liége, Liége.
Institut des Sciences naturelles de Belgique, Brussels.
Société Belge de Géologie, de Paléont. et d'Hydrologie, Brussels.
Institut de Botanique, Université de Liége,
Societe Royale Zoologique de Belgique, Brussels.

Brazil

Departamento de Zoologia da Secretaria da Agricultura, S. Paulo.
Servico Florestal do Brasil, Rio de Janeiro.

Bulgaria

Academie bulgare des Sciences, Sofia.

Canada

Department of Agriculture, Ottawa.
Geological Survey of Canada, Ottawa.
"Le Naturaliste Canadien", Quebec.
McGill University, Montreal.
Nova Scotian Institute of Science, Halifax.
Royal Canadian Institute, Toronto.
Royal Society of Canada, Ottawa.

Czecho-Slovakia

Astronomical Institute of Czecho-Slovakia, Prague.
Ceskoslovenska Entomologicka Spolecnost, Prague.
Ceskoslovenska Zoologiska Spolecnost, Prague.
Narodni Museum, Prague.
Studia botanica cechoslovaca, Prague.

Denmark

Dansk Naturhistorisk Forening, Copenhagen.
Kon. Danske Videnskabernes Selskab, Copenhagen.

England

Agent-General for Victoria, London.
Balfour Library, London.
Bodleian Library, Oxford.
British Museum, London.
Dove Marine Laboratory, Cullercoats, Northumberland.
Eugenics Education Society, London.
Fisheries Laboratory, Lowestoft, Suffolk.
Geological Society of London, London.
Geologists' Association, London.
Imperial Institute of Entomology, London.
Imperial College of Science and Technology, London.
Lawes Agricultural Trust, Harpenden, Herts.
Linnean Society, London.
Manchester Literary and Philosophical Society, Mancester.
Liverpool Biological Society, Liverpool.
Liverpool School of Tropical Medcine, Liverpool.
Manchester Museum, Manchester.
Marine Biological Laboratory, Plymouth.
National Physical Laboratory, Middlesex.
Natural History Museum, London.
"Nature", London.
Patents Office, London.
Philosophical Society, Cambridge.
Reference Library, Liverpool.
Royal Anthropological Institute, London.
Royal Botanic Gardens, Kew, Surrey.
Royal Empire Society, London.
Royal Geographical Society, London.
Royal Microscopical Society, London.
Science Abstracts, London.
Science Museum, London.
University Library, Cambridge.
Zoological Society of London, London.

Finland

Geologinen Tutkimuslaitos, Helsinki.
Societas Scientiarum Fennica, Helsinki.
Societas pro Fauna et Flora Fennica, Helsinki.

Soc. Zoo. Bot. Fennica Vanamo, Helsinki.
Suomalainen Tiedeakatemia Library, Helsinki.

Formosa

National Taiwan University, Taipei.

France

Faculté des Sciences, Marseilles.
Société des Sciences Naturelles de Dijon, Dijon.
Société des Sciences Naturelles de l'Ouest de la France, Nantes.
SociétéGeologique du Nord, Lille.
Société Nationale des Sciences Naturelles et Mathematiques, Cherbourg.
Société Scientifiques de Bretagne, Rennes.
Société Zoologique de France, Paris.

Germany

Akademie der Wissenschaften, Gottingen.
Bayerische Akademie der Wissenschaften, Munich.
Deutsche Akademie der Naturforscher, Halle.
Deutsche Geologische Gesellschaft, Hannover.
Deutsche Wetterdrenst, Hamburg.
Geographische Institut der Universitat, Greifswald.
Gesellschaft für erdkunde, Berlin.
Hessisches Landesamt für Bodenforschung, Wiesbaden.
Naturforschende Gesellschaft Universitats, Freiberg.
Museum für Natur-, Volker- und Handelskunde, Bremen.
Naturhistorisch Verein der Rheinlande u. Westfalens, Bonn.
Nassauischer Verein für Naturkunde, Wiesbaden.
Naturwissenschaftlicher Verein für Scheleswig-Holstein, Keil.
Oberhessische Gesellschaft für Natur-u. Heilkunde zu Gissen, Giessen.
Sachs. Akademie der Wissenschaften, Leipzig.
Senckenbergische Naturforschende Gesellschaft, Frankfurt on M.
Universitat Heidelberg, Heidelberg.
Zoologische Staatinstitut u. Zoologische Museum, Hamburg.

Gold Coast

Geological Survey Department, Saltpond.

Greece

Hellenic Hydrobiological Institute, Piraeus.

Hawaiian Islands

Bernice Pauahai Bishop Museum, Honolulu.
University of Hawaii, Honolulu.

Holland

Geologisch Bureau, Heerlen.
Geologisch en Mineralogisch Institute, Leiden.
Kon. Nederlandsche Akademie Van wetenschappen, Amsterdam.
Mineralogisch-Geologisch Institut, Utrecht.
Musée Teyler, Haarlem.
Nederlandsche Botanische Vereeniging, Leiden.
Ned. Geologisch Mijnbouwkundig Genootschap, Delft.
Provincial Utrechtsch Genootschap van Kunsten, Utrecht.
Rijks Herbarium, Leiden.
Technical University, Delft.

Hungary

Magyer Tudomanyos Akademia Konyvtara, Budapest.

India

Asiatic Society of Bengal, Calcutta.
Ceylon Journal of Science, University of Ceylon, Colombo.
Geological Mining & Metallurgical Society of India, Calcutta.
Geological Survey of India, Calcutta.
Imperial Institute of Agricultural Research, Pusa.
Indian Chemical Society, Calcutta.
Indian Museum, Calcutta.
Journal of Scientific and Industrial Research, New Delhi.
National Institute of Sciences, New Delhi.
Mysore University Journal, Mysore.
Zoology Department, East Panjab University, Panjab.

Ireland

Belfast Natural History and Philosophical Society, Belfast.
Royal Dublin Society, Dublin.
Royal Irish Academy, Dublin.
Trinity College Library, Dublin.

Italy

Accademia di Scienze, Modena.
Accademia Nazionale dei Lincei, Rome.
Istituto di Entomologia, Bologna.
Istituto di Entomologia Agraria della Universita, Milano.
Istituto e Museo di Zoologia, Turin.
Revista di Biologia Coloniale, Rome.
Societa Geografica Italiana, Rome.
Stazione Zoologica di Napoli, Napoli.

Java

Bibliotheca Bogoriensis, Buitenzorg.
Indonesian journal nat. sci., Bandung.
Library, Chronica Naturae, Bandung.
Meteorologische en geophysische dienst, Djakarta.

Japan

Hokkaido University, Sapporo.
Kumamoto University, Kumamoto.
Ohara Instituts fur landwirtschaftliche Forschungen, Okayama.
Tokyo College of Fisheries, Tokyo.
Tohoku University, Sendai.

Mexico

Academia Nacional de Ciencias, Mexico.
Escuela Nacional de Ciencias Biologicas, Mexico.
Instituto de Biologia, Universidad nacional de Mexico, Mexico.
Instituto de Geologia, Universidad nacional de Mexico, Mexico.

New South Wales

Australian Museum, Sydney.
Australian Veterinary Association, Glebe.
Botanic Gardens, Sydney.
Department of Agriculture, Sydney.
Department of Mines, Sydney.
Linnean Society of New South Wales, Sydney.
New England University College, Armidale.
Public Library, Sydney.
Royal Society of New South Wales, Sydney.
School of Public Health and Tropical Medicine, Sydney.
Technological Museum, Sydney.
University Library, Sydney.

New Zealand

Auckland Institute and Museum, Auckland.
Canterbury Museum, Christchurch.
Dominion Museum, Wellington.
Geological Survey, Wellington.
Otago University, Dunedin.
Royal Society of New Zealand, Wellington.
Zoology Department, Victoria University College, Wellington.

Norway

Kongl. Norske Videnskabers-Selskabs, Trondhjem.
Norske Videnskaps-Akademi i Oslo, Oslo.
Nyt Magasin for Naturvidenskabene, Oslo.
Tromso Museum, Tromso.
Universitet, Bergen.
Université Royale de Norvege, Oslo.

Pakistan

Pakistan Association for the Advancement of Science, Lahore.

Peru

Cuerpo de Ingenieros de Minas y Aguas del Peru, Lima.

Poland

"Acta Geologica Polanica", Warsaw.
Institut Zoologique de l'Academie Polanaise des Sciences, Warsaw.
Polska akademia umiejetnosci, Krakow.
Musee Zoologique Polanais, Warsaw.
Uniwersytet Marii Curie—Sklowskiej, Lubin.

Portugal

Associacao da Filosofia Natural, Porto.
Instituto botanico da Universidade de Coimbra, Coimbra.
Laboratorio de Fisica, Faculdale de Ciencias, Lisbon.

Queensland

Geological Survey Office, Brisbane.
Queensland Museum, Brisbane.
Royal Geographical Society, Brisbane.
Royal Society of Queensland, Brisbane.
University of Queensland, Brisbane.

Rhodesia

National Museum of Southern Rhodesia, Bulawayo.

Roumania

Mathematical Institute, Polytehnica "Gh. Asachi", Jassy.

Scotland

Botanical Society of Edinburgh, Edinburgh.
Royal Physical Society of Edinburgh, Edinburgh.
Royal Scottish Geographical Society, Edinburgh.
Royal Society of Edinburgh, Edinburgh.
University of Glasgow, Glasgow.

South Australia

Department of Mines, Adelaide.
Public Library, Adelaide.
Royal Geographical Society, Adelaide.
Royal Society of South Australia, Adelaide.
South Australian Museum, Adelaide.
University of Adelaide, Adelaide.
Waite Agricultural Research Institute, Adelaide.

Spain

Academia de Ciencias exactas, fisicas y naturales, Madrid.
Jardin Botanico, Madrid.

Sweden

Library, Entom. Dept., Museum of Natural History, Stockholm.
Kungl. Universitet, Bibliotek, Upsala.
Kungl. Vetenskaps-och Vitterhets-samhalle, Goteborg.
Kungl. Svenska Vetenskaps akademi, Stockholm.
Sveriges Geologiska Undersoking, Stockholm.
Statens Vaxtskyddsanstalt, Stockholm.
Universitets-Biblioteket, Lund.

Switzerland

Naturforschende Gesellschaft in Basel, Basel.
Naturforschende Gesellschaft in Zürich, Zurich.
Schweizerische Naturforschende Gesellschaft, Berne.
Société de Physique et d'histoire Naturelle, Geneva.

Tanganyika Territory

Geological Survey Department, Dodoma.

Tasmania

Geological Survey, Mines Department, Hobart.
Royal Society of Tasmania, Hobart.
Royal Society of Tasmania, Launceston.
University of Tasmania, Hobart.

Tunis

Societe des Sciences Naturelles de Tunis, Tunis.

Union of South Africa

Durban Museum, Durban.
Geological Society of South Africa, Johannesburg.
Geological Survey, Pretoria.
Nasionale Museum, Bloemfontein.
Natal Museum, Pietermaritzburg.
Royal Society of South Africa, Capetown.
S. African Assoc. for the Advancement of Science, Johannesburg.
South African Museum, Capetown.

United States of America

Academy of Natural Sciences, Philadelphia.
Academy of Science of St. Louis, St. Louis.
"Acquisition Division", Albert R. Mann Library, Ithaca, N.Y.
Allan Hancock Foundation, University Park, Los Angeles.
American Academy of Arts and Sciences, Kansas City.
American Geographical Society of New York, New York.
American Microscopical Society, East Lansing.
American Midland Naturalist (University of Notre Dame), Notre Dame.
American Museum of Natural History, New York.
American Philosophical Society, Philadelphia.
Arnold Arboretum, Harvard University, Jamaica Plain.
Buffalo Museum of Science, Buffalo, N.Y.
Bureau of Economic Geology, University of Texas, Austin.
Bureau of Ethnology, Smithsonian Institution, Washington, D.C.
Bureau of Standards, Department of Commerce, Washington, D.C.
California Academy of Sciences, San Francisco.
Chicago Natural History Museum, Chicago.
Citrus Experiment Station, Riverside, Cal.
Connecticut Academy of Arts and Sciences, New Haven.
Department of Agriculture, Library, Washington, D.C.
Department of Geology, Mines and Water Resources, Baltimore, Md.
Exchange Department, University of Kansas, Lawrence.
Illinois State Natural History Survey, Library, Urbana.
Florida Geological Survey, Tallahassee.
Franklin Institute of the State of Pennsylvania, Philadelphia.
Iowa Academy of Science, Iowa State College Library, Ames.
Iowa Geological Survey, Iowa City.
Johns Hopkins University, Baltimore.
Kansas State College of Agriculture and and Applied Science, Manhattan.
Library, Division of Technical Service, State College of Washington, Washington, D.C.
Lloyd Museum and Library, Cincinnati.
Marine Biological Laboratory, Woods Hole.
Missouri Botanic Garden, St. Louis.
Museum of Comparative Zoology, Harvard College, Cambridge.
New York State Library, Albany, N.Y.
North Dakota Geological Survey, University Station, Grand Forks.
Ohio Academy of Science, Columbus.
Oklahoma Agricultural and Mechanical College, Stillwater.
Oklahoma Geological Survey, Norman.
Princeton University, Princeton.
San Diego Society of Natural History, San Diego.
Smithsonian Institution, Washington, D.C.
Stanford University, California.
State University of Iowa Libraries, Iowa City.
United States Coast and Geodetic Survey, Washington.
United States Geological Survey, Washington, D.C.
United States National Museum, Washington, D.C.
University of California, Berkeley.
University of California at Los Angeles, Los Angeles.
University of Illinois, Urbana.
University of Michigan, Ann Arbor.
University of Minnesota, Minneapolis.
University of Missouri, Columbia.
University of Washington, St. Louis.
University of Washington, Oceanographic Laboratories, Seattle.
Wisconsin Academy of Sciences, Arts and Letters, Madison.

Uraguay

Sociedad de Biologia de Montevidea, Montevideo.

U.S.S.R.

Academy of Science U.S.S.R. Botanical Journal, Leningrad.

Victoria

Australasian Institute of Mining and Metallurgy, Melbourne.
Chief Secretary's Office, Melbourne.
Department of Agriculture, Science Branch, Melbourne.
Department of Mines, Melbourne.
Field Naturalists Club of Victoria, Melbourne.
Free Library, Geelong.
National Herbarium, Melbourne.
National Museum, Melbourne.
Parliamentary Library, Melbourne.
Public Library, Melbourne.
Royal Australian Chemical Institute, Melbourne.
School of Mines and Industries, Ballarat.
School of Mines and Industries, Bendigo.
Society of Chemical Industry, Melbourne.
University Library, Carlton.

Western Australia

Geological Survey Office, Perth.
Royal Society of Western Australia, Perth.
University Library, Perth.
West Australian Museum and Art Gallery, Perth.

Yugoslavia

Academie Serbe des Sciences, Central Library, Beograd.
Crustvo Mathematicara I Fizicara Nrh, Zagreb.
Hrvatsko Prirodosclovno Drustvo, Zagreb.
Slovenska Akademija znanosti in umetnosti, Ljubljana.

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